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From an old wood-cut illustrating the fall of the Meteor before Ensisheim in 1492
(see page 407)

PLATE XXIV

CHARLES ALBERT BIGGER
Born August 15, 1853; died November 9, 1923

THE JOURNAL
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OF CANADA

VOL. XVII NOVEMBER-DECEMBER No. 9-10

CHARLES ALBERT BIGGER,

ASSISTANT SUPERINTENDENT OF THE GEODETIC SURVEY OF CANADA

By F. A. McDIARMID

ON the afternoon of Friday, November 9th, in his office at the Geodetic Survey Building at Ottawa, Mr. Charles Albert Bigger, the Assistant Superintendent of the Survey, suddenly passed away. Mr. Bigger, up to the very moment of his death, was actively engaged in the work of the Survey, and apparently in fair health. A year or so ago he had suffered a severe illness, but he had regained much of his former vigour, and his friends looked for many years of usefulness in his chosen profession. He leaves to mourn his loss, his widow, formerly Miss Louise Cockburn Brennan of Ottawa, and one daughter, Mrs. J. A. M. Dawson of San Francisco. To these and to those other near friends and relations is offered the sincerest sympathy.

Mr. Bigger, of United Empire Loyalist stock, was born at Oakville, Ontario, on the 15th of August, 1853. His father was Colonel James S. Bigger and his mother Amelia Kenny. He received his early education from the public school of his native town and at the Toronto Normal School, and also from private tuition. He

attended the Royal Military College at Kingston, from which he graduated in 1874. After graduation Mr. Bigger decided to enter the engineering profession and engaged in survey work in the field. In 1878 he was articled to an Ontario Land Surveyor and received his professional diploma in 1882. In the early part of 1882 he also passed the examination of a Dominion Land Surveyor, and during that season was engaged in surveying and marking base lines and township boundaries in what is now Northern Saskatchewan. In 1883 Mr. Bigger was Travelling Inspector of Surveys, covering that district of Western Canada lying between the fourth initial meridian and the Rocky Mountains and between the Red Deer River and the International Boundary.

He continued in the employ of the Dominion Government till 1888 when he took up private practice in the Ottawa district, where for thirteen years he was engaged in engineering work. Monuments to mark his surveys are found to-day scattered over the counties of Carlton, Russell, Prescott and Glengarry. His work was of the highest standard of efficiency. A fellow surveyor, in speaking of Mr. Bigger a short time ago, said that it was always strictly safe to assume Mr. Bigger's azimuths as absolutely correct. No higher compliment could be paid an engineer. In the city of Ottawa his marks can be found in many parts of the city. Especially in the districts known as the Glebe and Hintonburgh, the major portion of the subdivision work was done by him. In 1901 Mr. Bigger again entered the Government Service, as the Canadian engineer in the re-survey of the New York-Quebec Boundary Line. He made all the astronomical observations for latitude and azimuth, and it was the privilege of the writer of this brief sketch to act as Mr. Bigger's assistant in part of this work. Mr. Bigger had the delicate touch of the skilled observer and his handling of instruments, and his ceaseless care to secure the most reliable results made him a master in field astronomy. In 1904-05 he was engaged in boundary survey work in Alaska.

In 1905, in co-operation with the late Chief Astronomer, Dr. W. F. King, Mr. Bigger commenced work on what is now the Geodetic Survey of Canada. Dr. King was appointed Superintendent, and Mr. Bigger Assistant Superintendent, with the direction of the field operations. For the last eighteen years Mr.

Bigger had used his unbounded energy, his wide experience and his good ability to establish the Geodetic Survey of Canada on a sure and firm foundation. He personally supervised the early work in Ontario, Quebec and British Columbia.

It will serve no useful purpose to go into the details of the field work of the Survey, it is sufficient merely to bear testimony to the fact that as long as the work of the Survey lives, the name of Mr. Bigger will be honoured as one who gave to it the best he had. There is just one part of the Survey equipment that is most worthy of special mention, that is the Standards Building. The equipment was gathered together by Mr. Bigger and the building designed and constructed under his personal supervision. It is of the highest efficiency and is the greatest safeguard to the accuracy of the Survey.

Mr. Bigger was an honoured President of the Royal Astronomical Society of Canada, Ottawa Centre. The years of his presidency were times of real progress and a resolution in the minutes of the Society show the high regard in which he was held. He was also an associate member of the Engineering Institute of Canada.

In his death, Canada has lost a faithful public servant, the Geodetic Survey an officer who did much for its progress, and those who had the pleasure of his acquaintance a good friend. All can say that he ran a good race, he kept the faith and his native land is the better and the richer for his presence. All unite in extending heartfelt sympathy to those left behind.

VENUS: EVENING AND MORNING STAR

From Tennyson's *In Memoriam*, Canto 121

Sad Hesper o'er the buried sun
  And ready, thou, to die with him,
  Thou watchest all things ever dim
And dimmer, and a glory done:

The team is loosen'd from the wain,
  The boat is drawn upon the shore:
  Thou listenest to the closing door,
And life is darkened in the brain.

Bright Phosphor, fresher for the night,
  By thee the world's great work is heard
  Beginning, and the wakeful bird:
Behind thee comes the greater light:

The market boat is on the stream,
  And voices hail it from the brink;
  Thou hear'st the village hammer clink,
And seest the moving of the team.

Sweet Hesper-Phosphor, double name
  For what is one, the first, the last,
  Thou, like my present and my past,
Thy place is changed; thou art the same.

Venus became an evening star on September 10, 1923, and will continue to be one until July 1, 1924.

AURORAE, SUNSPOTS AND MAGNETIC VARIATIONS DURING 1921

By W. E. W. Jackson

IT has generally been accepted that there is some definite relation existing between the aurora, the amount of spottedness of the sun and the variations observed in the terrestrial magnetic field. Observations of these various phenomena indicate particularly a periodicity of about eleven years, during which the maximum and minimum of aurorae, of sunspots and of magnetic storms occur synchronously; or very nearly so. In fact, this view has become so pronounced that many believe the presence of a single spot on the sun is indicative of magnetic storms or of an auroral display. Such, however, is not the fact.

In order to impress this on the mind of the reader the accompanying chart was prepared, showing graphically the variations actually observed during the year 1921.

The upper row of small circles is inserted to indicate the time of full moon, for at that time it is always more difficult to observe an aurora unless it is very brilliant, and the first curve which is intended to represent the changes in auroral intensity must not be given too much weight at or near full moon. This curve was prepared from the reports made by meteorological observers whose stations are scattered over Canada from the Atlantic to the Pacific. The ordinate of the curve represents the total number of observers who report having seen an aurora on any particular day without regard to its class. No allowance has been made for weather conditions, on account of the extent of country occupied by observers. If clouds should interfere in some part of the country it is fairly safe to assume that it is not cloudy over a greater area and that the effect of cloudiness on a single day's reports is constant throughout the year. It is also considered that more brilliant aurorae are seen by more observers and therefore the actual number

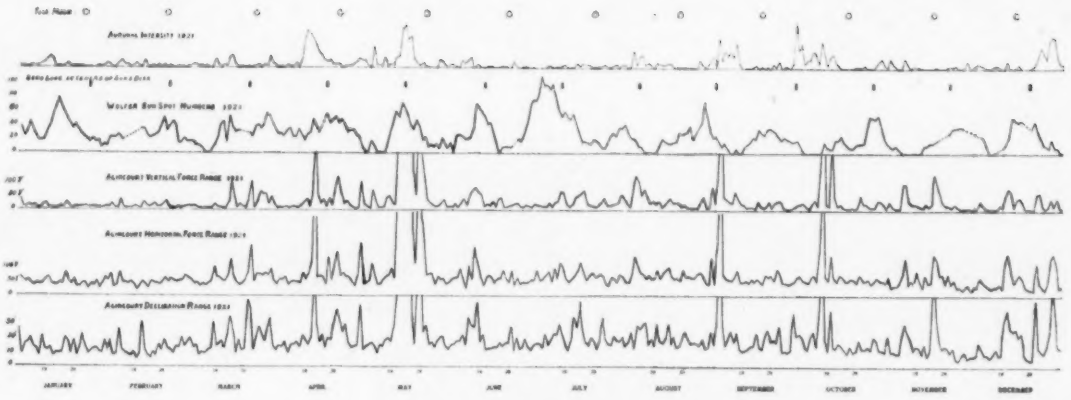


CHART I

Curves illustrating the relation between aurorae, sunspots and magnetic intensity during 1921.

of observers reporting gives a good relative value of the intensity from day to day.

The row of dashes shows the day on which the zero longitude of the sun is central on the sun's disc and this, in conjunction with the sunspot curve, which is plotted next, indicates that spottedness was not a function of any particular longitude of the sun. The sunspot curve was obtained from Wolfer's provisional sunspot numbers published in *Terrestrial Magnetism* for December, 1921. The number for each day was entered as ordinate and the points so obtained were joined by straight lines. Where more than a day was missing the line joining the nearest days for which reports were given is a series of dots. The Wolfer numbers are obtained from visual counts of the spots and groups which are combined by the formula $s = 10g + f$ where s is the spot number, g the number of groups and f the number of spots.

The remaining three curves were obtained from the Agincourt records of the vertical force, horizontal force and declination. The ordinate for each day is the difference between the maximum and minimum as recorded photographically and expressed in gammas (.00001 C.G.S. units) for vertical and horizontal force and in minutes of arc for declination.

An examination of these curves shows that the facts of observation on individual days would give little support to the theory that the three phenomenon observed are simply different manifestations of some unknown solar force.

The greatest maximum of sunspots occurred during the period from June 25 to July 10, when the moon was new, and yet the auroral intensity was almost nil and the magnetic ranges at a minimum. A smaller maximum of sunspots is also recorded on Jan. 14 and Oct. 23, with similar conditions in auroral and magnetic phenomena. On the other hand, from May 10 to May 20 the period of greatest magnetic variations was coincident with a maximum of sunspots and auroral display. A slightly less intense period of magnetic activity from October 8 to 11 occurred during an almost spotless period on the sun and with only a very moderate amount of aurora.

The auroral intensity curve and the magnetic ranges synchronize much better than either of them do with the sunspot curve. There

is, however, one outstanding departure. On September 28 the greatest number of observers reported seeing the aurora whilst for some days both before and after the magnetic ranges, except for declination, were near the minimum, and in declination the range was by no means a large one.

That there is some connection between the changes taking place in the earth's magnetic field and in the spottedness of the sun would, however, seem to be established by an examination of the average values taken over a period of years. If we take the period from the establishment of the magnetic observatory at Agincourt in 1898 up to 1921 and form a table of the average daily range by years and compare it with the mean sunspot numbers, it is noticed at once that increasing values of the magnetic ranges occur with increasing values of the sunspot numbers.

In the accompanying table, in the columns headed Do and Ho, are given the observed mean daily ranges of declination and horizontal force at Agincourt and in the last column headed S the Wolfer sunspot numbers. These S numbers up to and including 1918 are taken from the *Astronomische Mitteilungen*, and the remaining ones from provisional values published in *Terrestrial Magnetism* for September, 1920, and December, 1921.

If the magnetic ranges are plotted as ordinates with the sunspot numbers as abscissae it is apparent that a linear function will express very well the relation between them. Assuming then a relation of the form

$$R = A + B.S$$

where R represents the range and S the sunspot number and A and B are unknown coefficients the 23 normal equations for both declination and horizontal force ranges were formed. The least square solution gave the following results:

For declination, $R = 8.'374 + 0.0343\ S$

For horizontal force, $R = 27.926\gamma + 0.2209\ S.$

AGINCOURT MEAN MAGNETIC RANGES AND WOLFER SUNSPOT NUMBERS

Year	Do	Dc	o−c	Ho	Hc	o−c	S
	′	′	′	γ	γ	γ	
1899	8.56	8.79	−0.23	28.7	30.6	−1.9	12.1
1900	8.47	8.70	−0.27	28.8	30.0	−1.2	9.5
1	8.06	8.47	−0.41	26.7	28.5	−1.8	2.7
2	8.56	8.54	+0.02	31.0	29.0	+2.0	5.0
3	8.83	9.21	−0.38	33.1	33.3	−0.2	24.4
4	9.45	9.81	−0.36	36.0	37.2	−1.2	42.0
5	9.31	10.55	−1.24	37.9	42.0	−4.1	63.5
6	9.01	10.22	−1.21	32.6	39.8	−7.2	53.8
7	9.42	10.50	−1.08	40.4	41.6	−1.2	62.0
8	9.65	10.04	−0.39	34.8	38.6	−3.8	48.5
9	9.25	9.88	−0.63	28.7	37.7	−9.0	43.9
10	9.44	9.01	+0.43	35.4	32.0	+3.4	18.6
11	8.73	8.56	+0.17	31.9	29.2	+2.7	5.7
12	8.53	8.49	+0.04	27.2	28.7	−1.5	3.6
13	8.83	8.41	+0.42	29.3	28.5	+0.8	1.4
14	8.64	8.70	−0.06	28.5	30.0	−1.5	9.6
15	10.17	10.00	+0.17	37.2	38.4	−1.2	47.4
16	10.79	10.33	+0.46	45.0	40.5	+4.5	57.1
17	12.41	11.94	+0.47	52.5	50.9	+1.6	103.9
18	11.90	11.14	+0.76	48.4	45.7	+2.7	80.6
19	11.42	10.54	+0.88	46.8	41.9	+4.9	63.1
20	11.00	9.70	+1.30	44.2	40.5	+3.7	38.7
21	10.36	9.22	+1.14	38.7	33.4	+5.3	24.7

Using these formulae and the value of S for the different years the value of the Declination and Horizontal Force ranges were computed. The computed values are given in the table under Dc and Hc. The difference between observed and computed values are also given under the heading o − c.

These results are also shown graphically in Chart II.

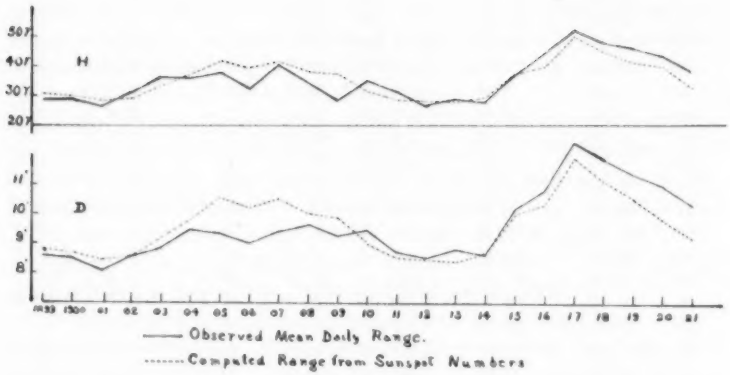


CHART II

Comparison of the observed mean daily range of the changes of the earth's magnetic force and that deduced from the sunspot numbers.

GRAVITY RESULTS IN THE MACKENZIE BASIN

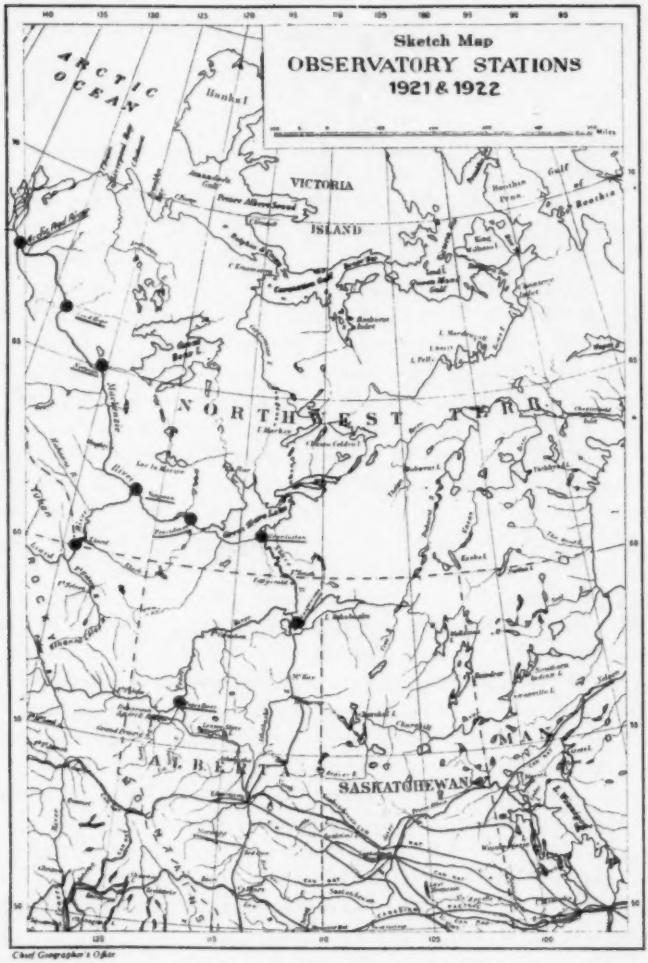
By A. H. Miller

DURING 1921 and 1922 nine gravity stations, which are shown on the accompanying sketch map, were established by the Dominion Observatory in the Mackenzie River basin. The latitudes of the stations range from 56° 14′ to 67° 27′.

The determinations, which are relative to Ottawa, were made with a half-seconds pendulum apparatus of the Mendenhall type. Three bronze (invariable) pendulums, each of approximately one-half second period, constitute the pendulum set. In some cases only two pendulums were used but at most of the stations observations were taken with all three. Concrete piers were erected on which to set up the apparatus; the flexure was measured with an interferometer. At all the stations, with the exception of Peace River, the only one on a telegraph line, the rates of the chronometers were obtained from the Annapolis wireless signals. These were determined by Mr. J. P. Henderson, who made the time comparisons in the field. The corrections to the signals were determined by comparison with the standard observatory clocks.

The observations that are required to determine the force of gravity at the field stations are merely those that are necessary to obtain the times of vibration of the pendulums at these places. By comparing these with those obtained at Ottawa (where the force of gravity is known) the value of gravity at the various places is easily computed. The force of gravity at Ottawa has been obtained from relative determinations that have been made with Washington, which has in turn been connected with Potsdam, Germany and other European stations. The gravity determinations made in this country (there are now 51 stations) are therefore comparable with those that have been made in other countries throughout the world.

Although the pendulums are spoken of as invariable (which has reference to length and distribution of mass, two of the factors



Map showing gravity stations occupied.

which determine the time of vibration of a pendulum), they are really invariable only if we disregard the unavoidable changes that are due to variations in temperature and to other causes. As it is not possible to control entirely the conditions of temperature and pressure to which the pendulums are subjected during the observations, corrections are applied to reduce all observations to some standard temperature and pressure. In addition to these a correction is required to take account of the daily rates of the two chronometers in terms of which the periods are first determined. Corrections which are comparatively small are also made for the amplitude of swing and for the vibration (flexure) of the pendulum support which is caused by the swinging of the pendulum.

Owing to the fact that bronze expands considerably when its temperature increases, the temperature correction is one of the largest that has to be applied. For these pendulums it amounts to 41.9×10^{-7} seconds per degree centigrade.

The apparatus, its use and the method of reducing the observations are described in a previous paper in this JOURNAL (Vol. X, No. 10, "Gravity," by F. A. McDiarmid).

Some of the more important results of the observations in the Mackenzie district are summarized in the tables at the end of this article. The periods of the pendulums in seconds at the various stations and the resulting value of the force of gravity in dynes are given in the first table. Of the field stations Peace River, Resolution, Providence, Simpson and Norman were established during 1921, while the remaining stations with the exception of Ottawa were established during 1922. Two determinations of the periods at Ottawa were made each year at the beginning and end of the season and the mean of the two has been taken for the field work of the corresponding season. It will be noted that the quantities given for the periods of the pendulums are carried out to the seventh place of decimals or to the ten-millionth of a second. At any particular standardization at Ottawa separate determinations of the period of any given pendulum almost invariably agree to within a few units of the seventh place and in the field the agreement is usually nearly as good.

In Table II are given the principal facts for each station. The names, longitudes, latitudes and elevations of the various

stations are shown in columns 1 to 4. Column 5 gives the value of g computed from Bowie's formula $\gamma_0 = 978.039\ (1 + .005294\ \sin^2\phi - .000007\ \sin^2 2\phi)$, where γ_0 is the value of g at sea level and ϕ is the latitude. This formula was obtained by Bowie from 348 gravity stations in different parts of the world. The form of this equation is fixed by theory while the values of the constants, with the exception of the last, were determined from the gravity observations at the chosen stations.

Under the heading "Corrections" there is given first the altitude correction which represents the diminution of gravity due solely to elevation above sea level or the increased distance of the station from the centre of the earth. The second correction is based upon the theory of isostasy. It may be remarked that this theory is more successful in predicting observed values of gravity than any other method that has yet been suggested. For this reason the gravity anomalies given by it have a greater significance than those obtained by other methods.

The fundamental assumption of the theory of isostasy is a distribution of material in the crust of the earth that causes equal normal pressures to be exerted on equal elements of a surface which is everywhere at the same depth below sea level and which encloses the whole body of the earth with the exception of the outer crust. The depth at which this equilibrium in pressure is reached is called the depth of compensation. It follows at once from this assumption that the continents are compensated by deficiencies of matter below sea level and that the oceans, on account of their lower density, must be balanced by excesses of matter underneath. These excesses or deficiencies are spoken of as the compensation. In computing the influence that it has on the force of gravity at the station the compensation in the entire crust of the earth is taken into account. Along with this, in order to obtain the quantities in column 6, there has also to be considered the effect of topography. The topography includes all matter in the crust of the earth above sea level and the water of the oceans. For the purpose of computing these corrections, readings are taken from the best topographical maps available and use is then made of tables which simplify the work very much. The tables, published by the United States Coast and Geodetic Survey, have been used in this reduction. The depth of compensation assumed is 113.7 kilometres.

When the corrections for altitude, topography and compensation are applied to the computed values of g at sea level the theoretical values required by the theory of isostasy are obtained. These values are given in column 7, while those obtained from the pendulum observations are given in the next column. The gravity anomalies, that is the difference between the observed and computed values of gravity, are given in the last column. A positive anomaly indicates an excess of gravity at the station, while a negative anomaly indicates a deficiency.

The anomalies have also been computed for several other assumed depths of compensation. If Bowie's formula is used to obtain the value of g at sea level it has been found, by a least square solution, that the depth of compensation which fits the results for the nine field stations best is 91 kilometres. Owing to the small number of stations the probable error of this quantity is rather large—29 kilometres.

An older formula of Helmert's, $\gamma_0 = 978.030\ (1 + .005302\ \sin^2\phi - .000007\ \sin^2 2\phi)$, gives a depth of compensation of 67 kilometres with a probable error of 20 kilometres.

There is not a sufficient number of stations to attach much significance to these two results. They are, however, a rough confirmation of the order of magnitude that has already been found for the depth of compensation and to some extent they give an idea of the depth in the area under consideration.

TABLE I

Station	Periods of Pendulums in Seconds			Value of g in Dynes			
	1	2	3	1	2	3	Weighted Mean
Ottawa (April 20-23, 1921)	.5013471	.5014646	.5014385	.....	.....	.....	980.618*
Peace River	.5011254	.5012430	.....	981.482	981.482	.....	981.482
Resolution	.5010084	.5011252	.5010985	981.941	981.943	981.945	981.942
Providence	.5010040	.5011225	.5010966	981.958	981.954	981.953	981.955
Simpson	.5009925	.....	.5010833	982.003	.....	982.005	982.004
Norman	.5009385	.5010563	.5010295	982.215	982.213	982.215	982.214
Ottawa (Oct. 27-Nov. 4, 1921)	.5013455	.5014628	.5014365	.....	.....	.....	980.618*
Ottawa (Feb. 25-27, 1922)	.5013464	.5014635	.5014373	.....	.....	.....	980.618*
Liard River	.5010460	.5011635	.5011377	981.790	981.790	981.789	981.790
Good Hope	.5009058	.5010234	.5009969	982.340	982.339	982.341	982.340
Arctic Red River	.5008820	.5009990	.....	982.433	982.435	.....	982.434
Chipewyan	.5010627	.5011810	.5011555	981.724	981.722	981.720	981.723
Ottawa (Nov. 7-18, 1922)	.5013442	.5014624	.5014364	.....	.....	.....	980.618*

*Adopted value.

TABLE II

Station	Longitude	Latitude	Altitude	Computed g at sea-level	Corrections		Computed Gravity	Observed Gravity	Gravity Anomaly O—C
					Altitude	Topography and Isostatic Compensation			
	h m s	° ′ ″	metres	dynes	dynes	dynes	dynes	dynes	dynes
Ottawa	5 02 52	45 23 38	83	980.656	−.026	−.008	980.622	980.618	−.004
Peace River	7 49 09	56 14 04	324	981.612	−.100	−.038	981.474	981.482	+.008
Resolution	7 34 42	61 10 05	152	982.008	−.047	−.009	981.952	981.942	−.010
Providence	7 50 37	61 21 14	156	982.022	−.048	−.018	981.956	981.955	−.001
Simpson	8 05 23	61 51 39	132	982.061	−.041	−.023	981.997	982.004	+.007
Norman	8 22 17	64 53 59	87	982.281	−.027	−.036	982.218	982.214	−.004
Liard River	8 15 10	59 58 43	160	981.915	−.049	−.059	981.807	981.790	−.017
Good Hope	8 34 33	66 15 18	59	982.374	−.018	−.029	982.327	982.340	+.013
Arctic Red River	8 54 57	67 26 37	41	982.452	−.013	−.026	982.413	982.434	+.021
Chipewyan	7 24 35	58 42 44	229	981.815	−.071	−.012	981.732	981.723	−.009
Mean anomaly with regard to sign									.000
Mean anomaly without regard to sign									.009

Dominion Observatory,
Ottawa, Canada.

AURORAE AND RADIO

By J. P. Henderson

WHEN we see some majestic sight, some brilliant display, we appeal also to our other senses to join in its appreciation, to give us evidence also of its greatness. We never see the steam from a distant whistle, the rise of masses of earth from a dynamite blast, without waiting and expecting to hear also the accompanying sound that, somehow by long experience, we have become accustomed to expect. So also, when we see flashing streaks of light in the sky, should we not also expect to hear a crackle much as of a bolt of lightning, or when we see curtains waving high over our heads should we not expect to hear the rustle as though great sheets of silk were being folded and unfolded round about us? These things we expect, our minds are ready to grasp them, our imaginations are whetted up and even the most careful scientist may be prone to connect the distant puff of steam with the sound of a whistle he thinks he hears following, and yet that puff may have been the exhaust from an engine and may never have made a sound. As we stand muffled up in our furs in the stillness of the northern night, as we watch the bright stars inlaid in the great canopy of blackness, then up rises a great curtain, waves above us, around us apparently, grows coloured at its lower edges, and again fades from our sight. As we marvel at the apparition, is it possible to establish absolutely whether we also heard it?

This was the writer's experience while viewing many beautiful displays in the North West during the last two summers. Also, all those with whom the matter was discussed said they had sometimes thought they heard it, and, considering the deep stillness of nights of great auroral displays, it is hard to believe that they did not perhaps hear it and that there was not some sound, some rustling or perhaps even crackling sound connected with it and really audible.

There are two different kinds of static known to wireless operators: (1) clicks, (2) hisses or constant sizzling. Most writers

on the topic have added another, (3) grinders, but this might be considered as a combination of the other two, produced at some distance.

(1) Clicks are sharp short knocks, often found to be directional, probably produced by a sudden discharge to earth or between clouds, such as lightning, that ceases instantly when the adjustment of potential difference is accomplished. The spark originally was probably oscillatory. They are produced in the laboratory by single sparks of an induction coil or Leyden jar. There seems to be no relationship between prevalence of clicks and radio receiving conditions, sometimes clicks being bad and yet signals strong, at other times clicks being of but medium strength and yet signals hopelessly weak. They are generally worst in bright sunny weather and where thunderstorms form, such as around Great Slave Lake during June and July when there were great differences of temperature between the lake and air. Some writers connect these clicks with streamer aurorae, and if so, there would be no relative good or bad receiving conditions accompanying, which appears to be true.

(2) Hisses usually indicate a constant discharge, the result of charging of regions of the atmosphere or clouds caused by the condensation of vapour and the liberation of much surface energy from the droplets. This manifests itself as electricity charging aerials and producing a constant flow, often of several microamperes, as if the earth were relatively negative though often reversing polarity. This usually accompanies hail, snow (or rain) blizzards, or the first stages of the rain in a thunder shower, and is generally local. During the actual existence of such a strong discharge to earth, usually brief only, signals may be "mushed" up or smothered, but, in general, fair to good receiving conditions exist along with these phenomena. It may be compared to a brush discharge between two highly charged points brought near each other, which when a glow or only a brush discharge occurs (in place of a spark or condenser discharge with polarity reversing at very high frequencies) indicates a strongly stressed dielectric condition of the medium.

Let us look for a moment at some similar phenomena reproducible in our laboratories. We can produce a glow in a Geissler tube between electrodes sealed in the ends; we can easily produce

a similar glow by induction by using high frequency currents in a coil surrounding a similar tube but without terminals sealed through the glass, or in any way by which we can cause currents of electricity to actually pass through the rarefied gas. These glows merge into what is called the coronal discharge as the pressure is increased and as the applied voltage is sufficient, and finally become the brush discharge as the dielectric commences to break down. In the highly evacuated tube the discharge itself is white or slightly bluish or greenish by contrast (it is out of our present scope to discuss the mechanism of the light production, the kinds of ionisation and lengths of the paths of electrons, these giving often a false idea of the actual light inside the tube due to bombardment and fluorescence of the glass walls), as the pressure is increased or certain gases or vapours admitted the colour becomes reddish or may be still more highly coloured, depending on the spectral lines emitted.

It appears as though the lower edges only of curtain aurorae are purplish. This may be because there is a discharge at this point in denser air—and no farther than a generally sharp lower edge because the pressure is so great that the electricity cannot easily enough pass. Unequal pressures throughout the upper air (which result in transfer of air from place to place, or winds) will offer greater or less resistance to the discharge, which will, accordingly, take on the many variable forms regularly seen, (such as arc, curtain, streamer, etc.), depending both on those differences of pressure and on the electric forces. Thus is possible an explanation of the relation between the forms of many aurorae seen and cirrus, or the higher level, clouds whose shape also depend on the air currents present.

In this we are assuming that there are present on these occasions at least the forces necessary to induce a discharge or passage of electricity from place to place in the atmosphere—these forces may be the flow of electrons say from our sun and passing our earth (as well as striking it and charging it electrically) but these streams of electrons are equivalent to currents of electricity which produce magnetic fields, which latter also in their turn induce flows of electricity—but the earth currents and magnetic fields become irregular, due to the permanent magnetism of the earth and the presence of bodies of iron, etc., in the earth's crust. The

new flows of electricity in the atmosphere are thus distorted largely from the directions of the original forces which caused them. When a sunspot is either on the limb or in the centre of the sun there is supposed to be additional electron emission; this may be supposed to supply, along with the rotation of the earth, the variable factors for the distortion of these forces and currents, when they thread through uneven conductors like the earth's crust containing metallic as well as other deposits.

We naturally expect such displays only when the air is not too much ionized, as it is with direct sun's rays, when it would be a good conductor and the transfers of the quantities of electricity would be accomplished without much rise in potential; also when there are not very strong winds which would effect the transfer by actually carrying the one charged region from place to place and preventing its potential rising to any such value as would be necessary to produce say a smooth curtain discharge or aurora. Observers tell us that aurorae are seldom accompanied by any wind whatever—they usually occur when the whole vault of heaven is so tranquil we would say we can "feel the stillness"—the absolute quiet is often appalling as we watch the great flitting glories passing above.

The photographs taken by Störmer in the north of Norway indicated not only the geographical location of the aurorae he selected but also their heights, ranging mostly from 50 to 200 km. high. This was a great advance in our knowledge on the subject but it should not be understood that there were no other aurorae, perhaps higher and lower, which however did not lend themselves to scientific measurement and which might be more likely to produce sound. It is scarcely conceivable that such as were located could yield any sound at the observer's station, and probably even amongst the display it would be so attenuated as not to produce anything audible.

It should be remembered, however, if the glow producing the "rustling" sound is at some distance from the observer the sound might be expected to lag after the appearance of the flash or wave of the curtain. This would not be true of the wireless "hiss" which should be and was found to be simultaneous on the many occasions observed. Nights when fine aurorae were displaying themselves overhead were remarkable not only for good receiving conditions

but also because of the profound stillness the faintest sounds in the receivers could much more easily be heard. In practically all cases the appearance of a specially bright display or a sudden wave of a curtain was simultaneously accompanied by a "hissing" sound in the receiving set—such a sound as is unmistakably like the leakage of electricity from a charged body, or the corona effect and approaching the brush discharge; this corona and the more violent brush effect appears particularly strongly around the sharp edges or points of charged bodies at ordinary air pressures and becomes, as the pressure is lowered, nothing else but the vacuum discharge of the Geissler tube.

It is thought by many that when aurorae are present we can expect specially good receiving conditions for long distance wireless. To a limited extent this is true and was verified particularly in presence of arc and curtain forms; but it might be better to say that it is the stillness of the air during these times, the absence of ionising agents such as sunlight, and the absence of water vapour in unstable conditions (the nights are usually cloudless)—these are all conditions conducive to the possibility of high potentials existing comparatively near to each other—that are responsible for aurorae and also good receiving conditions. We then have available a medium which appears to be the nearest approach to the true perfectly elastic ether dielectric, because no inductive energy is lost in partial conductors along the path of the transmission.

SUMMARY

With the sharp electrical discharges, possibly also streamer aurorae, clicks are heard in Radio receivers, and no particular relation was found to exist as regards good or bad reception. Clicks and grinders are probably results of thunder storm conditions somewhere. With corona and brush discharges, also waving curtain aurorae, hisses are heard—it is likely that with aurorae like sounds might be produced, but of such audibility outside of its wireless manifestations or its laboratory analogues there is still question. Good receiving conditions nearly always accompany arc and curtain aurorae.

Dominion Observatory,
Ottawa, Can.

THE SHADOW BANDS AT THE AUSTRALIAN ECLIPSE

By Jean L. Chant

THE task assigned to me was to observe the shadow bands and to test the general illumination of the sky. About 100 yards southeast of the Canadian observatory the ground had been levelled, and two pieces of fresh cotton duck, 9×10 feet in size, had been spread out. They were pinned down at each corner, in order to keep them flat. A light rod about six feet long rested on each sheet and was pivoted on a nail at the middle of the sheet. It could be revolved so as to take any direction in the horizontal plane. I was to watch closely for the bands and, as soon as they appeared, to begin to count seconds and to continue counting until the beginning of totality.

There was some doubt in my mind as to whether I should see the shadow bands, but no doubt as to the wonderful view I was to have of the eclipsed sun, as I was away from the little wattle trees and absolutely alone, with nothing to distract my attention.

Some considerable time after first contact, when the moon had moved well over the face of the sun, the astronomers took their places at their instruments and I stood beside one of the sheets. "Six minutes before!" called out Mr. Kean, who was announcing time for the American and Canadian parties. The darkness was rapidly coming on and the landscape assumed a peculiar greenish hue, as if a storm were approaching. The seconds went by and I felt rather nervous as this was my first experience of the kind.

Suddenly, and before I had expected it, the shimmering, elusive wave-like shadows began to sweep over me and the sheet. I grasped the rod and moved it back and forth until it was parallel to the crests of the waves as they moved forward. At the same time I began counting seconds—"one-and, two-and, three-and, etc."—and I continued counting up to 150 before totality was announced. I think perhaps I counted a little too rapidly and, allowing for

that, I judge that the bands began approximately 2¼ minutes before totality. They continued to move over me for only a short time, perhaps ten seconds, and then they were gone! They were faint, thrilling, ghost-like, but definite enough for me to be sure that I had seen the shadow-bands.

I then got ready to expose a camera which Dr. Young had prepared. In it was a photographic plate behind a brass plate in which holes of various sizes had been drilled. At one minute after totality began I exposed this camera and left it open to the sky for four minutes.

When two minutes of the total phase had elapsed I tried to read printing from four sizes of type which had been chosen for me. The first, I am told, was pica or 12-point old style. It was easy. The next was bourgeois, or 9-point, and this was rather hard. The third was a pocket Testament printed in nonpareil antique or 6-point. This was very hard. The fourth was the licence at the front of the Testament. It was set in pearl or 5-point italic, and I could not read it at all.

I was awed and filled with wonder at the beautiful sight in the sky. As there was a little time free I made a sketch of the corona on the board to which the paper containing my record was tacked, in order to fix my view of the corona and for my own satisfaction. The sketch impressed the form of the streamers on my mind as perhaps nothing else would have done.

Having closed the camera I took my position at the second sheet to watch for the shadow-bands again. They began at 15 seconds after totality and to my great surprise they seemed to come from the opposite direction. They were even fainter than at the beginning and lasted perhaps five seconds. I moved the second rod until I judged it was parallel to the crests of the waves.

At the beginning of totality the bands came from west to east, moving in the same direction as did the moon's shadow as it swept across the earth; at the end they moved in the opposite direction, or so it seemed to me.

While the rods lay in their position a pencil mark was drawn along each in order to record the direction of the wave-crests. This line was continued across to the edge of the sheets. A vertical rod was then driven in the ground at the end of each of these straight

lines, and next day observation showed that the sun's shadow fell along the first line at 11h. 1m. 45s., and along the second line at 11h. 5m. 45s., Western Australian Standard Time. Results deduced from these observations are given in a note by my husband at the end of this brief account.

In the evening after the eclipse a candle was held at different distances from the various printed pages and it was found that when it was 2 feet away the illumination was approximately equal to that from the sky at the middle of the eclipse.

I also endeavoured to measure the space occupied by three waves and also by the dark portion of a single wave, but the bands were so fugitive and so faint that no definite measurements were possible. I was also asked to estimate the speed at which the bands moved, and I judged that it was far greater than four miles per hour, but I could not give any definite value.

Note by C. A. Chant

As stated above, the direction of the line of crests of the shadow-bands seen before totality was the same as the azimuth of the sun at 11h. 1m. 45s. W.A.S.T. (120th meridian) on September 22. At this time the hour angle of the sun was -0h. 48m. 34s., its decl. $+0°\ 40'.5$, and the latitude of the station was $-19°\ 44'$. From these values the azimuth of the sun is found to have been $211°\ 40'$, or $31°\ 40'$ E. of N.

For the bands seen after totality the observed direction of the crests was the same as the azimuth of the sun four minutes later. Taking the hour angle of the sun as -0h. 44m. 34s. and the declination the same as before, the azimuth is deduced to have been $209°\ 27'$, or $29°\ 27'$ E. of N.

It is altogether likely that the direction was really the same in the two cases, and the mean of $31°\ 40'$ and $29°\ 27'$ is $30°\ 34'$ E. of N.

The middle of the eclipse was at 1h. 33m. L.M.T., and the hour angle of the sun then was $+1$h. 39m. 39s., while its declination was $+1°\ 1'$. Consequently its azimuth was $127°\ 28'$, or $52°\ 32'$ W. of N.

Hence the line of crests made with the vertical plane passing through the sun the angle $52°\ 32' + 30°\ 34' = 83°\ 6'$.

From a chart of the path of totality drawn by Mr. C. J. Merfield of the Melbourne Observatory and published by the Australian Government, the azimuth of the centre line of totality at Wallal was measured with a protractor and found to be 62° 30′ W. of N. Consequently the angle which the line of crests made with the direction of motion of the shadow cone was 62° 30′+30° 34′ = 93° 4′.

Now the observations of the direction of the line of crests could not be made with accuracy, and one is led to conclude that the line of crests was at right angles to the direction of advance of the shadow cone and tangent to it. It would be interesting to determine the line of crests at a point some distance from the central line of the path of totality, to see if it is always tangent to the cone.

The bands were seen 2¼ minutes before totality, and as the cone moved forward with a speed of about 25 miles per minute it would appear that the air producing the effect was about 56 miles in front of the cone. To the writer it seems almost certain that the bands are caused by the light from the slender crescent of the sun shining through layers of air of continually changing density. A similar appearance would be produced if the light passed through the quivering foliage of a tree and the tree was carried forward at the same time.

The second appearance of the bands was only about 15 seconds after totality and they lasted but a few seconds. From this one would conclude that the atmosphere became quiescent at a shorter distance behind the shadow cone than it was in front of it.

WIRELESS TIME SIGNALS OBSERVED AT OTTAWA

BULLETIN No. 5

1923 Date	Ottawa-Washington				Lafayette (G. Sid. T.)		ΔT at 10 p.m.	
	Observed		Corrected		1st Beat	300th Beat		
	Noon	10 p.m.	Noon	10 p.m.			Observed	Adopted
	s	s	s	s	h m s	h m s	s	s
May 1	+.13	+.12	+.05	+.06	10 42 30.15	10 47 23.31	.....	+1.644
2	+.10	+.11	+.02	+.02	43 47.96	48 41.13	+1.580	+1.590
3	+.08	+.12	.00	+.02	49 59.92	54 53.09	+1.544	+1.528
4	+.09	+.08	.00	−.01	56 11.47	11 1 4.63	+1.457	+1.462
5	+.05	+.04	−.01	+.01	58 27.33	3 20.49	+1.396	+1.393
6	.....	+.02	.....	+.01	11 2 40.99	7 34.14	+1.343	+1.307
7	+.01	−.01	.00	.00	7 52.93	12 46.09	+1.207	+1.201
8	+.04	+.07	−.03	−.01	10 8.31	15 1.47	.....	+1.031
9	+.06	+.07	−.03	−.02	14 20.98	19 14.14	.....	+0.869
10	+.08	+.10	−.01	+.01	20 30.76	25 23.91	+0.691	+0.700
11	+.12	+.14	+.02	+.04	24 42.08	29 35.24	.....	+0.538
12	+.14	+.15	+.03	+.05	23 0.03	27 53.18	+0.411	+0.399
13	+.11	+.13	+.01	+.03	28 9.96	33 3.12	.....	+0.246
14	+.05	+.06	.00	+.02	32 21.14	37 14.30	+0.089	+0.103
15	+.11	+.11	+.03	+.02	36 32.61	41 25.76	.....	−0.038
16	+.10	+.10	+.03	+.03	38 46.40	43 39.55	.....	−0.162
17	+.06	+.07	+.01	+.03	44 55.30	49 48.45	.....	−0.278
18	+.07	+.13	+.04	+.05	47 8.68	52 1.83	−0.388	−0.372
19	+.12	+.09	+.07	+.05	50 21.19	55 14.34	−0.454	−0.456
20	+.09	+.01	+.02	+.03	54 32.37	59 25.53	.....	−0.537
21	+.14	+.13	+.07	+.08	12 0 41.12	12 5 34.27	−0.618	−0.623
22	+.13	+.16	+.03	+.03	0 57.04	5 50.19	−0.731	−0.709
23	+.13	+.14	+.05	+.06	6 7.33	11 0.48	−0.783	−0.803
24	+.08	.....	+.03	.....	12 16.31	17 9.47	.....	−0.903
25	+.08	+.02	+.02	.00	16 27.18	21 20.33	−1.012	−1.010
26	+.03	+.04	−.01	.00	15 44.20	20 37.36	.....	−1.119
27	+.07	+.09	.00	+.02	22 51.89	27 45.05	.....	−1.226
28	+.06	+.05	+.01	+.03	25 6.03	29 59.18	−1.349	−1.361
29	+.10	+.09	.00	.00	30 24.66	35 17.81	.....	−1.504
30	+.09	+.10	.00	.00	32 40.02	37 33.17	−1.682	−1.653
31	+.08	+.08	−.01	.00	36 52.82	41 45.98	−1.748	−1.765

1923 Date	Ottawa-Washington Observed Noon	Observed 10 p.m.	Corrected Noon	Corrected 10 p.m.	Lafayette (G. Sid. T.) 1st Beat	300th Beat	ΔT at 10 p.m. Observed	Adopted
	s	s	s	s	h m s	h m s	s	s
June 1	+.06	+.08	−.04	−.01	12 41 6.02	12 45 59.18	.....	−1.872
2	+.07	+.10	+.01	+.04	47 17.76	52 10.92	.....	−2.011
3	+.14	+.14	+.08	+.08	50 33.16	55 26.32	.....	−2.154
4	+.12	+.13	+.07	+.08	53 48.28	58 41.44	.....	−2.259
5	+.12	+.11	+.05	+.04	.....	.....	.....	−2.362
6	+.08	+.06	+.01	.00	13 3 15.95	13 8 9.12	−2.471	−2.466
7	+.03	+.05	+.01	+.02	6 30.99	11 24.15	.....	−2.570
8	+.09	+.12	+.01	+.02	9 46.52	14 39.68	.....	−2.684
9	+.12	+.08	+.02	+.01	15 0.17	19 53.34	−2.799	−2.798
10	.....	+.07	.....	−.01	.....	.....	.....	−2.909
11	+.14	+.09	+.03	−.02	22 30.90	27 24.06	.....	−3.022
12	+.05	+.06	−.04	−.05	24 46.94	29 40.10	.....	−3.133
13	+.05	+.06	−.04	−.05	28 1.79	32 54.95	.....	−3.254
14	+.04	+.01	−.04	−.06	32 14.25	37 7.41	.....	−3.386
15	.00	−.03	−.04	−.05	36 26.87	41 20.03	.....	−3.520
16	−.01	−.06	−.05	−.03	.....	.....	.....	−3.657
17	+.05	+.03	−.03	−.04	43 53.78	48 46.93	.....	−3.789
18	+.01	+.04	−.07	−.02	53 0.53	57 53.69	−3.902	−3.912
19	+.08	+.09	−.01	+.01	50 22.08	55 15.24	.....	−4.059
20	+.15	+.14	+.05	+.03	56 33.52	14 1 26.68	−4.222	−4.223
21	+.09	+.11	+.01	.00	14 1 44.15	6 37.30	.....	−4.351
22	+.07	+.09	−.02	.00	5 56.03	10 49.19	.....	−4.496
23	+.08	+.07	−.01	−.01	.....	.....	.....	−4.630
24	−.01	.00	−.08	−.07	13 23.80	18.16 96	.....	−4.763
25	−.05	+.02	−.10	−.05	17 37.40	22 30.56	.....	−4.892
26	−.06	−.08	−.08	−.07	.....	.....	.....	−5.020
27	−.04	−.05	−.05	−.04	24 2.82	28 55.97	−5.172	−5.148
28	+.01	+.02	−.06	−.04	28 13.84	33 7.00	.....	−5.266
29	+.03	+.05	−.03	−.01	56 55.48	15 1 48.64	−5.358	−5.390
30	+.09	+.10	.00	+.01	41 30.52	14 46 23.68	−5.538	−5.532

1923 Date		Ottawa-Washington Observed Noon	Observed 10 p.m.	Corrected Noon	Corrected 10 p.m.	Lafayette (G. Sid. T.) 1st Beat	300th Beat	ΔT at 10 p.m. Observed	Adopted
		s	s	s	s	h m s	h m s	s	s
July	1	+.09	+.10	.00	−.01	14 40 49.19	14 45 42.34	.....	−5.670
	2	+.11	+.11	+.01	+.02	47 57.58	52 50.73	.....	−5.824
	3	+.10	+.10	+.01	+.03	.....	.....	.....	−5.963
	4	+.10	+.10	−.01	.00	52 24.89	57 18.04	−6.092	−6.110
	5	+.09	+.08	−.01	−.01	54 39.07	59 32.23	.....	−6.276
	6	+.10	+.10	−.01	−.02	.....	.....	−6.462	−6.442
	7	+.07	+.09	−.01	+.01	15 4 2.50	15 8 55.66	−6.595	−6.596
	8	+.10	+.09	+.01	+.02	9 13.49	14 6.64	.....	−6.752
	9	+.07	+.09	+.03	+.02	11 27.67	16 20.83	.....	−6.891
	10	+.06	+.05	.00	−.01	27 25.81	32 18.96	.....	−7.018
	11	+.01	+.01	−.01	−.02	19 51.83	24 44.99	−7.141	−7.150
	12	+.01	+.03	−.01	+.01	24 4.10	28 57.26	−7.326	−7.337
	13	+.01	−.01	−.01	−.01	29 15.11	34 8.26	.....	−7.513
	14	+.06	+.07	−.03	−.01	.....	.....	.....	−7.710
	15	+.08	+.10	−.01	.00	33 44.01	38 37.16	.....	−7.929
	16	+.10	+.07	+.02	+.01	40 51.42	45 44.57	−8.133	−8.136
	17	+.07	+.03	+.01	.00	44 3.05	48 56.20	.....	−8.311
	18	+.06	+.09	−.01	.00	46 15.57	51 8.71	−8.509	−8.496
	19	+.07	+.08	+.03	+.02	51 24.55	56 17.70	−8.701	−8.679
	20	+.12	+.11	+.03	+.03	54 35.77	59 28.92	.....	−8.808
	21	+.12	+.09	+.02	.00	57 47.39	16 2 40.53	−8.939	−8.948
	22	.....	+.10	.....	+.01	.....	.....	.....	−9.090
	23	+.06	+.04	.00	−.03	.....	.....	−9.247	−9.246
	24	+.08	+.06	+.02	.00	16 10 18.64	15 11.79	.....	−9.398
	25	+.03	+.02	−.01	−.01	.....	.....	−9.549	−9.559
	26	+.10	+.10	−.02	−.01	20 37.01	25 30.15	.....	−9.747
	27	.00	+.04	−.04	−.02	22 48.92	27 42.07	.....	−9.939
	28	+.04	+.02	.00	−.01	26 58.90	31 52.04	.....	−10.128
	29	−.03	−.06	−.05	−.04	35 4.04	39 57.18	.....	−10.319
	30	+.07	+.06	−.01	−.02	.....	.....	.....	−10.481
	31	+.05	+.07	−.01	.00	39 28.46	44 21.61	−10.661	−10.655

1923 Date	Ottawa-Washington				Lafayette (G. Sid. T.)		ΔT at 10 p.m.	
	Observed		Corrected		1st Beat	300th Beat	Observed	Adopted
	Noon	10 p.m.	Noon	10 p.m.				
	s	s	s	s	h m s	h m s	s	s
Aug. 1	+.07	+.05	−.01	−.03	16 43 38.10	16 48 31.21	.....	−10.837
2	+.04	+.07	−.03	−.01	45 50.35	50 43.51	.....	−11.015
3	+.09	+.09	−.02	−.01	.....	.....	−11.176	−11.212
4	+.04	+.06	−.05	−.05	.....	.....	.....	−11.433
5	+.06	+.06	−.02	.00	.....	.....	−11.704	−11.674
6	+.09	+.10	+.02	+.04	.....	.....	.....	−11.901
7	+.13	+.15	+.05	+.06	17 4 50.31	17 9 43.52	.....	−12.094
8	+.11	+.11	+.01	.00	.....	.....	−12.268	−12.269
9	+.05	+.05	−.03	−.02	14 42.06	19 35.27	−12.470	−12.465
10	+.07	+.03	−.02	−.01	29 26.26	34 19.48	.....	−12.665
11	+.06	+.01	−.01	+.01	26 31.37	31 24.59	.....	−12.851
12	+.06	+.05	+.02	+.03	.....	.....	.....	−13.029
13	+.04	+.04	+.04	+.04	36 13.19	41 6.44	−13.213	−13.221
14	+.05	+.11	.00	−.01	36 44.07	41 37.28	.....	−13.424
15	+.08	+.09	−.04	−.04	.....	.....	−13.637	−13.633
16	+.08	+.03	−.04	−.08	41 16.63	46 9.85	.....	−13.836
17	.00	+.05	−.08	−.06	.....	.....	.....	−14.036
18	+.06	+.08	−.05	−.03	.....	.....	.....	−14.228
19	+.20	+.19	−.03	−.02	.....	.....	.....	−14.436
20	+.06	+.09	−.03	.00	57 14.54	18 2 7.77	−14.650	−14.639
21	+.10	+.12	−.01	+.02	.....	.....	.....	−14.843
22	+.06	+.08	−.04	−.02	18 5 38.17	10 31.38	−15.014	−15.056
23	+.08	+.09	−.03	−.03	11 8.65	16 1.87	−15.316	−15.286
24	+.07	+.05	−.02	−.07	12 39.10	17 32.30	.....	−15.504
25	+.01	+.07	−.07	−.05	16 22.07	21 15.27	.....	−15.713
26	−.01	+.09	−.09	−.05	22 3.77	26 57.00	−15.913	−15.907
27	+.04	+.05	−.04	−.04	24 27.36	29 20.58	−16.109	−16.100
28	+.01	+.01	−.06	−.06	28 59.53	33 52.75	.....	−16.344
29	−.01	+.02	−.06	−.03	32 13.11	37 6.32	−16.507	−16.538
30	+.03	+.01	−.03	−.04	37 10.78	42 4.01	−16.778	−16.777
31	+.10	+.11	−.04	−.01	.....	.....	−17.036	−17.020

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CAN GRAVITATION BE EXPLAINED?*

By A. S. EDDINGTON

IN Einstein's theory the phenomenon of gravitation is shown to be a necessary consequence of the "curvature" (or non-Euclidean geometry) of the space and time around heavy masses. It is sometimes said that Einstein *explains* gravitation by attributing curvature to space and time; but this scarcely conveys the right impression of the purpose and achievement of his theory. The curvature of space-time is intended to be a description rather than an explanation. A region where gravitational effects are perceived differs in some way from a region free from gravitation; the intrinsic nature of this difference is necessarily beyond our comprehension, and we can only describe it by symbolism or analogy. Newton described the difference as consisting in the existence of an agent "absolute force," *i.e.*, something acting in a way analogous to the force of muscular effort with which we are directly familiar. Einstein describes the difference as a curvature, and his symbol takes shape in our minds by analogy with the curvature of surfaces. We believe that by Einstein's symbol a more accurate quantitative description of the facts is possible; but it does not profess to indicate the mechanism of the phenomena discovered and described in this way.

Nevertheless Einstein's theory makes some advance towards an explanation; at least it shows us more definitely what it is that requires explanation. Accepting his standpoint we have realized for the first time that a world without gravitation (without curvature) would be more specialized and stand more in need of explanation than the actual world disturbed by gravitation; just as the occurrence of a level lawn requires more explanation than the occurrence of an undulating field. This is an inversion of former ideas. The beginner in mechanics is taught that for every particle to move with uniform velocity in a straight line is a natural

*Reprinted from *Scientia*.

condition, but that any deviation from this orderly state must be explained as due to some outside cause. Surely this is to begin at the wrong end. *Order* requires explanation; *disorder* requires none—it is merely the indication of absence of controlling mechanism. It is because gravitation, though perhaps first appearing to us as a deviation from a more ideal type of order, does nevertheless impose an order on the motions, that Einstein's theory leaves something to be explained. Not the deviations, but the law of the deviations—not the existence of gravitation, but the law of gravitation—is the mystery to be explained. It is strange how we have puzzled ourselves by setting up a negation as an entity, and then tried to explain the occurrence of this entity. But having appreciated this, we have still the task of explaining the positive aspect of gravitation contained in the law which it recognizes.

Our problem then is to explain the occurrence of the order observed in motions of the planets and other bodies, this order being expressed by the law of gravitation. Einstein has traced it so far as to recognize that it is reducible to a law governing the curvature of space and time. Can we see any likely reason why the curvature of space and time should be subject to a law of any kind? Or can we suggest any mechanism by which the properties of space-time are adjusted so as to conform to this law? The first difficulty is that we seem here to be approaching the extreme limits of physical explanation. A particular phenomenon is said to have been explained when it has been traced to its source in the great fundamental laws of dynamics and physics; but here the problem before us is whether one of those fundamental laws can itself be explained. In pursuit of explanation must we not ultimately arrive at some statement of fact about the way the world is built which does not admit of further simplification? The final substratum or æther cannot be devoid of properties; can we do more than discover those properties without seeking to account for them? Nor ought we to expect that these properties will be of a type familiar in our experience of material bodies —rigidity, inertia, permanence—for whatever may be the nature of the substratum of the world, it is at least different from gross matter. If then Einstein's law of curvature of the world is merely a statement of the essential nature and properties of that continuum

from which all phenomena take their origin, we can scarcely hope to reach any further explanation. This stage is usually supposed to have been reached in the theory of the electro-magnetic field; the phenomena are reduced to a set of equations given by Maxwell and these are regarded as defining the æther in a way unlikely to be further simplified. We could only account for the properties of the æther by regarding it as a structure composed of some sub-æther not possessing those properties intrinsically; but the sub-æther itself could not be devoid of all properties, and these would have to be explained by reference to a sub-sub-æther—and so on *ad infinitum*.

Although we might have feared that the search for an explanation of the law of gravitation would be barred in this way, it appears that in fact it is not so barred. The law of world-curvature is not the expression of a property of the underlying substratum. It arises in a much more subtle way through the methods employed in investigating physical phenomena and the manner in which we represent to ourselves the results of those investigations. We shall see that from this point of view the actual law is one which might have been anticipated as inevitable.

Einstein's law of gravitation (or world-curvature) is usually expressed as a series of ten equations holding in empty space, which are written in the mysterious symbolic form

$$G_{\mu\nu}=\lambda g_{\mu\nu}.$$

The reader must turn elsewhere to learn how from these equations Einstein deduces that bodies will attract one another approximately according to Newton's law of the inverse-square, but with minute deviations verified observationally in the motion of the planet Mercury and the deflection of light-rays near the sun. Our task here is to understand why these particular equations and no others are satisfied in nature. One point, however, should be noticed. Newton's law of gravitation determined the force of attraction on a planet, but it had to be supplemented by other laws (the laws of motion) to discover how the planet would move under the influence of that attraction. Einstein's law needs no supplementing; it contains within itself the laws of mechanics—the conservation of energy and momentum—and determines both the field of gravitation and the motion of a particle in that field.

The law is frequently seen stated as $G_{\mu\nu}=0$; that is to say, the constant λ in the form given above is considered to be zero. The term $\lambda g_{\mu\nu}$ is usually called the "cosmical term" in the law of gravitation, because it is too small to be appreciable in the ordinary practical problems relating to the solar system, and could only rise to significance in problems on the vastest scale embracing the stellar universe and regions beyond. This term is, however, of great importance for our explanation of gravitation and it may be of interest to trace its history. Einstein first stated the law without the cosmical term, and introduced the term later. It has the effect of making the whole volume of space finite (although without a boundary). The non-mathematical reader will probably find it equally difficult to conceive space as infinite and space as finite—a well-known dilemma; but the mathematician can quite well grasp the conception of unbounded finite space, whereas infinite space is beyond the conception of everybody. Thus a quite unnecessary difficulty about contemplating infinity was removed, and in the view of the writer this is the primary recommendation of the cosmical term. The term was also supposed to remove a difficulty in regard to absolute rotation; but it may be doubted whether the difficulty was a real one, and whether the change cleared it away. Later on Weyl, in working out his more general theory, arrived directly at the law of gravitation with the cosmical term included; the constant λ performs an important function in his theory and cannot be put equal to zero, although it is certainly very small. We can scarcely do better than follow Einstein and Weyl in accepting the cosmical term as a necessary part of the law.

When written out in full the equations are of extreme complexity and forbidding technicality. Is there no more concise way of stating just what Einstein's law amounts to? Yes; by introducing geometrical nomenclature we can compress the law into a statement which is certainly not long-winded, and even seems to be on the verge of intelligibility! It runs

The radius of spherical curvature of a three-dimensional section of the world taken at any point and in any direction is always the same constant length.

This is exactly equivalent to the equations $G_{\mu\nu}=\lambda g_{\mu\nu}$, the constant length being $\sqrt{(3/\lambda)}$.

It seems as though with a little effort we might be able to picture the geometrical meaning of that statement, but I am afraid the hope is illusory. The principal difficulty is that no one is able to picture the curvature of a four-dimensional continuum because there is nothing in our experience which at all resembles it. Many geometrical conceptions based on ordinary space can be extended without much effort of the imagination to space of higher dimensions; but curvature is more baffling. Our experience of curvature of surfaces gives us simply no conception of the variety of contortions possible to a continuum of four dimensions. For one thing the continuum must be provided with six extra dimensions (ten dimensions in all) to twist about in, before it exhausts the variety of curvatures of which it is capable. An ordinary surface with radii of curvature the same at all points and in all directions would necessarily have the dull uniformity of a sphere. Not so a four-dimensional continuum; the law stated above imposes homogeneity and isotropy for a certain characteristic, but nothing like complete uniformity.

It is perhaps desirable here to emphasize the fact that in speaking of the curvature of space and time Einstein is using a symbol or analogy which is not to be understood too literally. Space and time together contain four dimensions, and if the combination were actually bent it would have to be bent in the direction of some fifth dimension outside both space and time. We do not believe that for a moment. The significance is that, owing to its non-Euclidean geometry, space-time has certain metrical properties, which if we were restricted to Euclidean geometry (which we are not) could only be accounted for by assuming it to be curved; we reject the restriction as unnecessary and irrational, but at the same time we find it convenient to retain the nomenclature which would result if the restriction were in force.

It would be a waste of time trying to visualize the curvature referred to in the geometrical statement of Einstein's law. What is essential to our purpose is that to every point and to every direction in empty space-time a significant length[1] can be associated; and whereas in an arbitrary continuum this length would vary

[1]We are dealing with time as well as space; but for simplicity I here confine attention to space, since that sufficiently illustrates the nature of the argument.

from point to point and from direction to direction, Einstein's law asserts that in actual space-time this length is a universal constant. The remarkable analysis of the relativity theory shows that the motion of the planets in their appointed orbits and all the orderly phenomena of gravitation result inevitably from this distinguishing characteristic of actual space-time; and accordingly our problem is to find out why actual space-time should be of this particularly limited type. We shall call this important length the radius of curvature in the direction considered, because it will be identifiable to mathematicians as the radius of spherical curvature of the corresponding section; but we do not ourselves need to trouble about that identification. Although the length is not a distance between two particular points it may be thought of as intrinsic in and characteristic of the region, much as the free period of a mechanical vibration may be thought of as a time-interval intrinsic in an object even if no oscillations are actually occurring.

Absolute size is as unimaginable as absolute velocity. A uniform change of scale of ourselves and all our surroundings would be undetectable if carried out with entire thoroughness. Size has a definite meaning for us, but it is a relative meaning; and it is necessary to examine precisely what this meaning is. Size is determined by reference to material standards, and we must not imagine that there can be any definition of size which dispenses with this reference to material objects. We say that a length AB is one metre if the standard metre (a material rod), when brought into the required position and orientation coincides with AB. There are also indirect (*e.g.*, optical) methods of determining the length AB; but these are justified because it is found by experiment that they give the same result as actual transference of the standard metre. Primarily therefore the measurement of a length involves transference of the material standard to the position and orientation required, followed by a direct comparison. No alternative method can be accepted unless it has been proved to be equivalent to this. Our previous statement of the law of gravitation can thus be amplified as follows. If the standard metre-rod is transferred to a particular point and direction, the radius of curvature at that point and in that direction will be a certain constant numerical multiple of the extension of the rod.

But this statement seems to contain an inversion of ideas "putting the cart before the horse." Would it not be more natural to say that when the standard metre is transferred to a new point and direction it takes up an extension which is a constant numerical submultiple of the corresponding radius of curvature there? There is, of course, no essential difference between the two statements; if one is true the other must be true; but the implication suggested is widely different. The law of gravitation no longer hints at a mechanism of adjustment of curvature in void regions; it is a statement of the adjustment of the extension of a material object as it is moved about.

When the standard metre is moved to a new position, how does it determine the extent of the region it ought now to fill? How do its individual molecules decide on their average spacing and settle down to the positions which determine the extension of the rod? Our first impulse is to reply that the rod solves the problem by remaining of the same size as it was before. But that is to argue in a circle. There is no absolute size. The rod is our standard metre and however it behaves it can never be anything but one metre long. To say that it will continue to extend one metre in the new position is merely to say that it will have to be the same size as itself. The fact that we are conventionally going to call its length one metre, and to measure all other lengths at the same point and in the same direction by comparison with it, cannot help the rod to solve the problem how to arrange its molecules in the new circumstances.

The spacing of the molecules will not be determined by memory of a former state but by the interplay of the various conditions which exist in the locality and affect the equilibrium. The rod has to find out its proper extension x having regard to these conditions of equilibrium; the mathematician might formulate the same problem as a series of equations, and solve them to find x. At present we are too ignorant to know what are the proper equations to write down; let us however anticipate future knowledge, and suppose that the equations have been discovered and solved, and that the mathematician has arrived at his answer

$$x = \text{something or other.}$$

It is well-known that in all such equations the physical dimensions of both sides must be the same. Since x is a length, the other side of the equation must also be a length. Moreover the problem was to find the length of the rod as determined by the conditions of the region in which it is placed, so that the length on the right side of the equation must be characteristic of the conditions of the region. Thus whatever may be the unknown equations, their solution will necessarily be of the form

> Length of rod = pure number × a length intrinsic in the region before the rod was inserted.

Since the problem must be solved afresh for every position and direction of the rod, the length intrinsic in the region must also be associated with position and direction.

It is not easy to find in an empty region of space-time a characteristic length associated with position and direction. But we have already noticed one such length, viz., the radius of curvature above-mentioned. Probably other lengths could be constructed, but these are highly complicated and it is difficult to regard them as more than ingenious exercises of the mathematician. Unless the conditions of adjustment of material structures are far more complicated than we have reason to expect, it is inevitable that the solution should take the form

> Length of rod = pure number × radius of curvature (for the position and direction considered) in the region where the rod was inserted.

But this is precisely what Einstein's law asserts.—Our last statement of the law was that "when the standard metre is transferred to a new point and direction, it takes up an extension which is a constant numerical submultiple of the corresponding radius of curvature there."

Instead of demanding a very specialized structure of the world we see that the law is so inevitable that we have arrived at it as the necessary solution without yet knowing the precise equations to be solved. Instances are not infrequent in physics, where by an argument from dimensions, the solution of a problem can be found (apart from an unknown numerical factor) without any

detailed study of the equations; we survey the various factors which can affect the solution, and if these can only be grouped in one way to give the right physical dimensions, this must necessarily be the solution (apart from an undetermined multiplier). The present argument is of this type.

The radius of curvature is the same at all points and in all directions simply because we accept it as the natural standard of length. It is too transcendental and inaccessible to be used directly as the practical standard; but any material structure adjusts its extension to a definite fraction of this natural standard (having nothing else to compare itself with), and so can be used equivalently as a more practical standard. In place of a separate standard at every point and in every direction, we can now use a single material rod as providing a standard for everywhere, since the material object can be moved about, whereas we cannot transfer the radius of curvature even in imagination. Since all the observations and deductions of physics are based on the acceptance of a material structure as standard of length, the resulting laws of physics will conform to the original convention that the radius of curvature is the standard to be regarded as constant. The law of gravitation is nothing more than a reiteration of this convention.

To sum up, the explanation of gravitation is divided into four stages:

1. We must realize that it is only in so far as gravitation is a law that the phenomena require explanation. The Newtonian tradition tends to emphasize what may be described as the *negative* aspect of gravitation—the substitution of less simple order for more simple order. We must dwell rather on the positive aspect and the mystery why there is any order at all in the world; and we seek an explanation of that constraint of phenomena which is manifested in its most varied form in the neighbourhood of heavy bodies, and comprises as a particular case the limiting condition of uniform motion in a straight line in regions remote from heavy masses.

2. This order is found by Einstein to arise from the fact that the equations $G_{\mu\nu} = \lambda g_{\mu\nu}$ are satisfied in empty space. The deduction is long and mathematical, and constitutes a great scientific achieve-

ment. We do not discuss it here since it is the well-known theory on which much has been written; there has been no lack of attempts to explain it in non-technical language so far as it admits of such treatment.

3. The interpretation of the equations $G_{\mu\nu} = \lambda g_{\mu\nu}$ is that space-time has a homogeneity and isotropy as regards a certain characteristic. The order, which we are seeking to explain, arises because actual space-time is not the most general type of metrical continuum imaginable by a mathematician, but is limited in this way. The property which is homogeneous and isotropic is a curvature (defined in a certain way); but it turns out to be unnecessary to our argument to enter on the question of its exact definition. The task before us is to explain why there is this kind of isotropy and homogeneity in the world.

4. The mystery of this isotropy and homogeneity disappears when we realize that it is not intrinsic in the external world, but in the measurements which we make of that world. Every measurement which we make is a comparison—a comparison of the region surveyed with the surveying apparatus. We must not ignore the second partner in the comparison, and suppose that every regularity in the results of our survey springs from a regularity intrinsic in the region surveyed. It may be a regularity of adjustment of one partner to the other. We have seen that from this point of view there is a perfectly natural explanation of the homogeneity and isotropy contained in our measurements. The surveying-apparatus has no *absolute* size and can only take up a definite extension by adjusting itself in a constant ratio to the linear characteristics of the region surveyed; when therefore we attempt to measure those linear characteristics with the apparatus we merely reproduce the constant ratio.

It is a well-known illustration of the special theory of relativity for uniform velocity, that on a planet travelling with high speed objects expand and contract as they change their orientation according to the FitzGerald-Lorentz law; and these changes are from their very nature undetectable by any measurements made on the planet. In just the same way if deviations from the above-mentioned isotropy and homogeneity of curvature occurred in any region they would be undetectable by any physical measure-

ments; the same deviations affect the measuring appliances as well as that which is measured and are eliminated in the comparison. We fail to find any deviations and consequently we announce that our survey of the world indicates complete homogeneity and isotropy of curvature, and thereby claim to have discovered a law of nature $G_{\mu\nu} = \lambda g_{\mu\nu}$. But the fact is that deviation from this law is unthinkable when we reflect on the nature of the operation we are performing when we make the measurements in question.

The space and time with which physics concerns itself—actual space-time—is an abstraction of the extensional relations of material objects. General space, with which the pure mathematician concerns himself, is a product of the imagination having no reference to material things. When we compare actual space-time with the mathematician's general space, we notice that the former is more specialized; and ultimately we trace the orderly phenomena of gravitation to this specialization. Our first impression is that the specialization is indicative of some controlling mechanism or design in external nature; but the true explanation is probably simpler. Why should our construct of actual space, abstracted out of the extensional relations, be judged by comparison with the mathematician's space constructed on different principles? The comparison is irrelevant. Let us instead turn to examine more minutely that process of abstraction by which we have chosen to construct actual space out of material extension; we then realize that it is not arbitrarily specialized but is of as general a character as could conceivably be consistent with such a mode of construction.

To give another illustration of the argument, consider a normal hydrogen atom which consists of one proton (or positive nucleus) and one electron at a distance apart which may well be used as the fundamental standard of length since it is accepted as a constant of nature. Keeping the proton at a fixed point, orientate the atom in all possible directions; the electron will then describe a certain locus. The atom is merely the mechanical means of making evident these loci intrinsic in space-time around every point. The loci have no shape or size in any absolute sense; but we adopt them as the standard of symmetry and equality, to which the relative terms "shape" and "size" are referred. Spheres are conventionally drawn by orientating a standard of length in all

directions, and the locus is called a sphere because of its method of construction—not from any quality discovered in the locus after its construction. In this way we have natural loci termed equal and spherical strewn all over space-time; when therefore we study the geometry of space-time we ought everywhere to come across these equal and spherical loci. That is just what we do find, and the discovery is called the law of gravitation.

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REVIEW OF PUBLICATIONS

Publications of the Astronomical Observatory of the University of Michigan (Detroit Observatory), Vol. III. (272 pages in 4to).

This volume constitutes a valuable addition to our knowledge of astrophysics. It is due chiefly to the efforts of Dr. Ralph H. Curtiss, whose studies on the stellar spectra containing emission lines are already widely known. The book contains articles by Dr. Curtiss, continuing his researches on bright line stellar spectra; Dr. R. H. Baker, giving an orbit of κ Draconis, and considering the fine absorption lines of hydrogen supposed on the wider emissions, as perhaps indicating that their origin is the same as that of the narrrow (stationary?) K line also found in the spectrum; Dr. F. Henroteau, showing the interesting abnormal behaviour of the H_ϵ line in the spectrum of σ Cygni; Dr. C. C. Kiess, advancing our knowledge of the peculiar astrophysical problem offered by the star α Canum Venaticorum and redetermining the radial velocity curve of the Cepheid variable RT Aurigae, showing considerably different characters than the curve determined previously at the Lick Observatory; Dr. Julia M. Hawkes, who gives photographic determinations of the position of stars and nebulous knots in the region of the Great Nebula in Andromeda; Dr. W. Carl Rufus, whose study of the silicon lines in class B stars, in collaboration with R. A. Sawyer and R. F. Paton, is of value, and whose illustrations of typical stellar spectra are of the best ever published. Dr. Rufus, it is known, has played an important part in the classification of stellar spectra by showing that classes R and N form a different sequence starting from class G, than classes K and M.

Professor William J. Hussey, director of the Observatory, and Dr. R. H. Curtiss have to be congratulated on the publication of such a magnificent volume.

F. HENROTEAU.

Yerkes Observatory. A selected list of 100 lantern slides, together with a description of each.

Some months ago reference was made in this JOURNAL to the selected list of 100 slides prepared by the Yerkes Observatory and offered for sale by the University of Chicago Press, Chicago. The lantern slides prepared at this observatory are unexcelled in variety and in quality and many of the photographs shown are unique. They hardly need further recommendation as they are so widely and favourably known. The usual price is 75 cents each slide, but when the entire set is taken the cost is $62.50.

Recently the value of the set, to most persons and institutions, has been greatly increased by the preparation of a concise description and explanation of each photograph, printed on separate cards, one for each slide. The text has been supplied by Professors E. B. Frost, S. B. Barrett and the late E. E. Barnard. With the assistance of these cards a very interesting lantern entertainment could easily be given. One need only choose a set of, say, forty slides and the corresponding cards and the programme is ready. The price is five cents for a single card or $2.50 for the complete set. Colleges and high schools will find this set of slides and cards a very valuable addition to their equipment.

C. A. CHANT.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

TENNYSON'S SCIENCE AND THAT OF HIS COMMENTATORS

It has often been remarked that Tennyson's references to science reveal closeness of observation and accuracy of knowledge, and it is unfortunate that a similar remark cannot be made regarding some of his biographers and commentators.

While reading Fausset's recently published volume entitled, "Tennyson: a Modern Portrait," I came across an account of the conferring of the D.C.L. degree on the poet by Oxford University in 1855. It is stated that after the ceremony,

> Tennyson obtained permission from the Master of Balliol, whose guest he was, to stroll, clad in his scarlet robes, amid the greenery of the garden. To be romantically magisterial was the need and satisfaction of all his later life, and the gorgeous figure perambulating the high-walled garden of Balliol is surely a parable in little of the poet who was increasingly content to be—a Laureate. In the evening, at Magdalen, he had an earnest talk with Mr. Gladstone, and on the following night took tea with two scientific professors and "looked at the Nebulae in Cassiopeia through the big telescope, the Ring Nebula in Lyra and also some double stars."

Undoubtedly the source of these statements is the "Memoir" by the poet's son, and there the account is as follows:

> My father, after luncheon, asked the Master of Balliol whether it would be against rule and propriety if he might have a smoke, as it was his fancy to do so, among the green trees when clad in his red doctorial robes. The Master said he might do so, and he smoked in the then walled-in Master's garden, now open to the college. In the evening at Magdalen he had long talks with Mr. Gladstone and Montalembert. Next day . . . at night they had tea with Professor Johnson and Professor Adams, and looked at the Nebulae in Cassiopeiae through the big telescope, the Ring Nebula in Lyra and also some double stars.

It will be noted that the two statements are not quite identical. The authoritative "Memoir" says he asked to *smoke* in the garden, while the later writer says he wished to *stroll*. Perhaps he did both, though the source of information does not say so. But the astronomer would like to know what nebulae in Cassiopeiae the poet looked at. Of course there are nebulae to be found within the area covered by this constellation, but they are faint and

unimpressive and would not be shown on such an occasion. Surely it was the Great Nebula in Andromeda which was observed, and the lack of an elementary acquaintance with the sky allowed his biographer to make the mistake, while his later critic simply perpetuated it.

The astronomer would also like to know what Professor Adams this was. The distinguished discoverer of Neptune (who was ten years younger than Tennyson) was, I believe, still at Cambridge, but he was not appointed professor there until 1859, and I do not find any reference to his being at Oxford at this time. The other professor was Manuel J. Johnson, who was director of the Radcliffe Observatory at Oxford, having been appointed to that post in 1838.

Perhaps my readers will say the above is only a slight error; but now let us turn to the edition of "In Memoriam" edited with a commentary by Arthur W. Robinson, B.D. (Cambridge University Press, 1904). When "explaining" canto 121, (see p. 360) in which Tennyson refers to Hesper and Phosphor, Venus being sometimes the evening and sometimes the morning star, the editor says:

> The question has been raised as to whether Tennyson meant that the evening star of one day actually appeared as the morning star of the next. It is just possible, it would seem, that this might be the case at mid-winter if Venus were very far north; but it would require a keen eye, and a knowledge of the exact position, to enable the observation to be made.
>
> The poet's reference is, no doubt, to the generally recognized fact that throughout the earlier half of the year Venus is seen as an evening, and throughout the other half as a morning, star.

Let us spend a minute looking into this remarkable elucidation. Venus is an evening star when it is east of the sun in the sky and consequently remains above the western horizon after sunset; when it is west of the sun in the sky it rises before the sun and appears above the eastern horizon as a morning star. The change from being evening star to being morning star, or the reverse, takes place when the planet is in conjunction with the sun, that is, when the earth, the sun and the planet are in line in space. At conjunction the planet's position in the sky (as seen from the earth) is very close to the sun and it cannot be observed. Indeed it cannot be seen for a considerable number of days (usually some weeks) before or after conjunction.

At mid-winter the sun is far south and low in the sky. In England, even at noon, it is less than 16 degrees above the horizon. At that time it is impossible for Venus to be "very far north"; and the suggestion that it can be seen in the west as an evening star and next day in the east as a morning star is preposterous.

The statement in the last paragraph is entirely without foundation. The intervals during which Venus is an evening or a morning star have no relation to the time of the year. For example, during 1923 Venus was a morning star until September 10 and it is an evening star for the rest of the year.

Astronomy in Bermuda

In the last number of the Journal Rev. E. D. Robinson, of Hamilton, Bermuda, published an article on "Bermuda and its Astronomical Needs." In this article the existing astronomical equipment, which is very meagre, was described and the importance of possessing a suitable astronomical and meteorological observatory pointed out.

Apparently those who are convinced of the need of a proper observatory have not been idle, for recently a deputation headed by the Rev. Dr. D. B. Marsh waited upon the governor of Bermuda to advise him of Bermuda's need in this respect and to ask that an observatory be built at Hamilton. It was suggested that the equipment of the observatory consist of a small equatorial clock-driven telescope fitted with the necessary cameras and with a grating spectroscope; an astronomical transit, to be used for obtaining the time and for rating and correcting the chronometers of ships calling at the island; a seismograph and the various meteorological instruments.

This proposal is now being dealt with by a select committee of the House of Assembly, who, it is hoped, will report favourably and thus enable Bermuda to have the observatory she needs.

Mira a Visual Double

Harvard College Observatory *Bulletin* 792 announces that on October 19th Professor Robert G. Aitken at the Lick Observatory found that o Ceti is a visual double, the companion being apparently

of a bluish colour and fully half a magnitude fainter than the variable star; it is 1″.01 distant, in position angle 132°.3. Examination of o Ceti by Professors Aitken and Doolittle in January, 1903, and December, 1905, respectively, gave no evidence of a companion. Possibly the separation has increased. Professor Barnard was unable to detect a second component during the minimum of the star in the preceding year.

On the basis of peculiarities in the spectrum, Joy had previously suggested that o Ceti might be a binary, composed of the variable with spectrum changing from M6c to M9e, and a faint star having an early type spectrum with strong omission bands of hydrogen and helium. He estimated the distance and position angle at 0″.3 and 135° respectively. Observations available at Harvard show that the magnitude of o Ceti on October 19, 1923, was 9.2. Since the parallax of o Ceti appears to be about $0''.04 \pm 0''.02$, the corresponding absolute magnitude of the two components combined was of the order of +7 on October 19.

In this connection our members will recollect that on October 16, speaking on the subject of Variable Stars in the constellation Cetus, Mr. Miller reviewed the theories usually advanced to account for the variation of o Ceti (Mira), pointing out what he regarded as very strong objections to the hypothesis of Zöllner, which assumed the existence of a bright area on the surface of a partially obscured rotating stellar body. He further held as untenable the "meteor swarm" theory proposed by Lockyer; and was also unable to find a satisfactory explanation in an assumption of recurring periods of activity similar in character to the sunspot cycle. He suggested that o Ceti might be a very close binary, or multiple, system, the principal member (the variable) having a companion with a period of about 331⅓ days revolving in a very elliptical orbit with plane approximately transverse to our line of sight. Assuming the principal star to be surrounded by a dense absorbing medium, this envelope would be subject to enormous tidal disturbance at each periastron passage, resulting in greatly augmented radiation for a short time. Perturbations by smaller members of the system would account for the irregularity of the 331 days period and the fluctuations in brightness at the maxima, and at other times.

Director Mitchell's Parallax Work

In the last issue reference was made to the recent publication by Dr. S. A. Mitchell, of the Leander McCormick Observatory, of the parallaxes of 260 stars, and the statement was made that this had surely kept his staff busy for a decade. The present writer was surprised to learn that the parallaxes of 350 additional stars are almost ready for publication. They will appear as a Memoir of the National Academy of Sciences.

Death of two Members of the Society

On November 6 John Ellis, J.P., died at his home in Swansea, a suburb on the west side of Toronto. He was in his 87th year and had lived in that district for many years. His family originally owned 250 acres bordering on Grenadier Pond and extending from the lake front to Bloor Street, more than a mile to the north. Various portions had been disposed of and at the time of his death Mr. Ellis retained only his picturesque home on "Herne Hill" and a small amount of the land about it.

For years Mr. Ellis was a lithographer and he possessed considerable skill in designing and drawing. He was an enthusiastic amateur astronomer and on several occasions open-air meetings of the Society were held on his grounds. Some years ago he acted as librarian of the Society. He also suggested the design for the Society's crest.

Wilson Taylor, B.A., died at his home in Toronto on October 3, 1923, in his 63rd year. Mr. Taylor was formerly a high school teacher and spent several years in Chatham, Peterboro' and St. Catharines. While teaching the subject of surface tension to his class in the last-named place, he was led to follow a line of reasoning which conducted him to some interesting results.

It is well known that around every drop of liquid there is a surface "skin", which exerts a tension and thus endeavours to make the drop spherical in shape. If in any way one increases the area of this surface "skin", he must do mechanical work, and the amount of the work done is proportional to the product of the surface tension and the increase in the area of the surface.

Suppose we begin with a spherical drop of water having a mass of one gram and hence a volume of one cubic centimetre. The area of its surface can easily be computed. Now let it be cut into two equal parts; each will assume a spherical shape. We can compute the total area of the surfaces of the two spheres and can thus determine the increase in the area. Multiplying this by the surface tension we obtain the work done. Again divide each sphere equally and in the same way compute the work done. By continuing the process we reach at last the molecules of water and the water will be in the form of vapour. On equating the total work done to the heat of vaporization of the water, we can determine the number of molecules in one cubic centimetre of water, the mass of each and also the space occupied by it.

Leaving his position at St. Catharines, Mr. Taylor went to Toronto to devote himself to research. For a short time he was supported by a grant from the Advisory Scientific Research Council at Ottawa. When this was no longer available he by chance met Col. R. W. Leonard, of St. Catharines, who at once became interested in the research and gave Mr. Taylor very generous support for about two years—until his death.

Mr. Taylor contributed scientific papers to the *Philosophical Magazine* (the leading English journal of physical science), to *Nature* and other publications. They all deal with molecular phenomena. In the course of his investigations he devised a method for treating hardwood logs to prevent them from sinking when being floated to the mill, and the Ontario Government is endeavouring to see if it is practicable on a large scale.

Mr. Taylor enjoyed few advantages when he was young and for much of his life his health was not good, but his indomitable will, great native ability and sturdy independence enabled him to excel in almost any subject to which he devoted himself. He had superior mathematical ability and if his steps had been directed into the path of research thirty years ago he would certainly have attained high distinction.

DEATH OF JAMES B. MCDOWELL.

It was with great regret that I learned of the death, on Thursday morning, November 29, of James B. McDowell, son-in-law and

successor to John A. Brashear, Pittsburgh, Pa. Mr. McDowell was one of the cleverest of opticians and his passing is a great loss to astronomy.

EPIGRAM

Pope's couplet on Newton is well known:

> Nature and Nature's laws lay hid in night;
> God said, "Let Newton be!" and all was light.

To this a Toronto professor (not in science) adds:

> Excessive light dazzles the eyes of men;
> God said, "Let Einstein be!" and all was dark again.

THE METEOR-FALL OF ENSISHEIM (1492)

Under the above heading the present writer presented a paper in this JOURNAL for September-October, 1914 (volume 8, page 349), in which it was stated that on the title page of the earliest publication describing this famous meteoric stone is a wood-cut representing the fall of the meteorite. A photograph of the picture had been promised but had not been received and so it was not possible to give it at that time. The continuance of the war prevented further inquiries for it; but recently Dr. O. C. Farrington, of the Field Museum, Chicago, obtained a facsimile of the original and he kindly had a photograph of it sent to me. It is reproduced in plate XXIII.

C. A. C.

MEETINGS OF THE SOCIETY

At Ottawa

February 27.—Dr. H. M. Ami, of the Geological Survey of Canada, gave a lecture on "Prehistoric life and the age of the earth."

Starting with the beginning of life on the earth, the speaker dealt with its progressive advancement throughout the ages. This was demonstrated not only by the types that are found in Canada, where the oldest formations are so well developed, but also in other parts of the globe. The different stages in the evolution of plant and animal life, the gradual change from the simple to more complex forms were traced.

With special reference to the last chapter in the history of this planet, Dr. Ami spoke of man and those types of higher life that have been discovered in different parts of the world and which have thrived since the time of the old stone age. The desire to advance, to progress, the power to go one better in all creation is one of the main factors leading towards regeneration and betterment on earth. It was also responsible to some extent for the consummate variety and beauty we have all around us in the organic world.

A brief reference was made to the manner in which the age of the earth is arrived at by the geologists. This had been estimated at about one hundred million years.

Some remarkably good lantern slides showing fossils that have been found in the different geological formations and others illustrating very early life were shown on the screen.

The President, Dr. R. J. McDiarmid, occupied the chair.

March 13.—Dr. W. Bell Dawson, Superintendent of Tidal Surveys, gave an address on "The influence of the Sun and Moon on the Ocean."

The effect of the sun is due mainly to its heat, and the evaporation of the water which it produces. This is the main cause of the circulations in the oceans; the warmer water flowing away from the equator, and being replaced by the cold water from the polar regions.

The only effect of the moon upon the oceans is due to its attraction, which causes the tides. The moon has no heat to offer; and it is often accused of many influences which it cannot be held responsible for. The sun also increases the tides by its attraction; but being so much further away, the resulting effect is less than half of the moon's influence. The tides respond to every change in the moon's position, as well as to variations in the distance of the sun and moon from the earth. A discussion of the tides is therefore well within the scope of the Astronomical Society, as they are in reality astronomy brought down to this world. The astronomer is thus apt to lay claim to the tide as being within his domain, although its behaviour becomes in reality a hydraulic problem in straits

and estuaries. On the other hand, the mariner from the practical standpoint claims the tide as his affair.

When the moon is in line with the sun, as it is when the moon is full or new, the two bodies act together, and the tide then is usually higher than at any other time in the month. This variation is the one usually explained in physical geographies and even in school atlases. But the impression is often given that this is the only variation in the tide, which is quite misleading. For example, in the Bay of Fundy the greatest variation in the rise of the tide is in accord with the change in the moon's distance. On our Pacific coast, as well as in some straits in Eastern Canada, the largest variation in the tide is due to another movement of the moon. On the various coasts of Canada, we have examples of every type of tide in the world. It is therefore a subject which should be of special interest to Canadians.

The investigation of the tides results in the publication of Tide Tables, accompanied by tables that show the time at which the currents turn. Any country without Tide Tables would be much hampered in carrying on its trade and commerce. Communities living inland are as dependent upon ocean navigation for the carrying of their exports and imports as are those who inhabit the maritime parts of the country. Tidal investigations and research work are therefore of value to the public in all parts of the country.

The meeting was well attended and among the audience were a number of teachers from the city schools and high schools.

The following were elected to membership in the Society: Mr. R. Callander and Mr. J. F. Fredette, of the Dominion Observatory, and Mr. Henri de Miffonis, 355c Kenniston Apartments, Ottawa.

March 27.—Mr. C. R. Coutlee, C.E., the Vice-President of the Ottawa Centre, gave a lecture on "The myths of the stars." This completed the series of five lectures that have been given before the Society during the winter term of 1923. (Mr. Coutlee's lecture has appeared in the JOURNAL under the title "Star Myths.")

AT TORONTO

May 15.—The regular meeting of the Society was held in the Physics Building of the University at 8 p.m., the President, Mr. W. E. W. Jackson, in the chair.

A communication from Mr. T. G. Walker, New Hamburg, concerning a flowing well was read and the President gave the physical explanation of the phenomenon.

The following were elected Members of the Society:

G. W. Allan, 9 Poplar Plains Road, Toronto.

H. Bibby, Meteorological Office, Bloor Street West, Toronto.

Dr. Chant read a communication from Mr. Hassard concerning the Planet Jupiter. On May 5th two stars were in view near the planet, giving it an appearance of having six conspicuous satellites; a sketch was given showing the relative positions of Jupiter, four of its satellites, and a double star in Libra.

Mr. A. F. Miller drew the Society's attention to the value of observing the bands of Jupiter over long periods in order to detect any variations in the appearance of these bands. He also pointed out the suitability of Saturn for observation.

Mr. Collins then read a paper, "Bermuda and its Astronomical needs," by Rev. E. D. Robinson, Hamilton, Bermuda.

Bermuda is a coral Archipelago more than seven hundred miles distant from the United States of America. The writer describes the complete lack of astronomical equipment until Rev. Dr. Marsh arrived there three years ago. Even now only three telescopes suitable for observation exist on the island and these are owned privately by Dr. Marsh, Mr. Robinson and the Public Library. Dr. Marsh, since his arrival, has made good use of all the available instruments. He and Mr. Robinson have mounted a transit on the wall of a stone house. Time is given to the island by using this instrument. Dr. Marsh also repaired and set up a Milne seismograph which had been allowed to get in bad condition through neglect.

The only other astronomical instruments on the island are those in charge of the military authorities set up on Prospect Hill, and these consist of barometers, thermometers and an anemometer. In addition to checking the time, Dr. Marsh takes many photographs of the sun and planets, while Mr. Robinson observes variable stars, being a member of the American Association of Variable Star Observers.

Those interested on the island are hoping to interest the Government to the extent of building a small observatory with a moderate equipment.

Several slides showing the instruments and nearby views in Bermuda were shown following the paper.

Mr. Miller then spoke, describing the methods he had used in examining the spectra of metals. In some cases we get the spectrum of the oxide and not that of the metal, *e.g.*, Calcium oxide. Metals in a metallic state in an electric arc give strong spectra, but they are not as good as those obtained from spark spectra using the pure metals. Many metals cannot easily be obtained in the pure form, *e.g.*, calcium, uranium, lithium, etc. Mr. Miller stated that he had obtained best results by using "lead" out of "lead" pencils soaked in the salt solutions for terminals with a spark spectrum. He had obtained, by this method, spectra of calcium, barium, lithium, etc.

May 22.—The Open Air meeting of the Society was held, use being made of the two four-inch telescopes on the University campus, and of the Meteorological Observatory instrument on Bloor Street West.

The weather was favourable and a large crowd viewed the moon, the planets Jupiter and Saturn, and various double stars. Observing continued with the observatory telescope up to 11.30 p.m. owing to the number of interested members.

October 16.—The regular meeting of the Society was held in the Physics Building of the University at 8 p.m., the President, Mr. W. E. W. Jackson, in the chair.

The chairman reported that a sunspot was now conspicuous, and an aurora had been visible on Monday night, October 15.

Mr. A. F. Miller read a paper on the Constellation Cetus in which he described its position in the sky and explained how to find it. It extends through right ascension three hours. Alpha Ceti is a large red variable star, which Mr. Miller described, and also how other stars in Cetus have varied in magnitude in historic times. The constellation is noted for its variable stars. Mira Ceti is the most interesting one, and was the first variable star identified as such.

In a paper on the "Toronto Observatory Record of the Japan Earthquake," Mr. Jas. Young of the Observatory described the Milne-Shaw seismograph, its equipment and its method of recording earthquakes. The distance of an earthquake from the instrument is determined by an examination of the P waves and the S waves which the instrument records. Mr. Young also described the method of damping the vibrations of the boom, by which the record is made more convenient. The amplitude of the Japan earthquake waves on reaching Toronto was 0.6 of a millimetre, or a little more than half a millimetre, which was the extent to which each particle of the earth was displaced at this point. This would be quite appreciable, but fortunately the time duration is considerable at so great a distance, and it is not detected, except by the seismograph. The address was illustrated by means of lantern slides.

Mr. A. F. Hunter gave an address on "Volcanic Action in the Earth and the Moon," using lantern views to illustrate the subject. Some examples of the earth's volcanoes still active were first shown, followed by a number of examples of volcanoes on the moon. The latter are probably now extinct, but those which show most recent formation are situated near the so-called "seas" of the moon, which are probably now silent and solid. This rule governs the position of the most active volcanoes of the earth at the present time. By far the largest part of the volcanoes of the earth are situated on a large circle occupied by the Pacific Ocean, the shores of which are the scenes of nine-tenths of the active volcanoes and destructive earthquakes. In conclusion, the outstanding features of the old volcanic area in Canada, which is the largest of its kind in the world, received due attention.

October 30.—A regular meeting of the Society was held in the Physics Building at 8 p.m., the President, Mr. W. E. W. Jackson, in the chair.

Mr. Jackson reported that since last meeting two small sunspot groups have been visible. Mr. A. F. Miller reported that on October 17 he had observed three small prominences on the sun's limb, but speaking generally prominences had not been numerous.

Mr. Jackson, according to arrangement whereby a constellation is briefly described at each meeting, gave some account of Pegasus, one of the larger constellations. It extends for three hours in right ascension and 36 degrees of declination. Some lantern illustrations of the constellation added to the interest of the description.

Prof. John Satterly, D.Sc., gave an interesting address on "The Solar Atmosphere; including information obtained at recent eclipses." He announced

that he would speak mainly of the flash spectrum and the corona. Beginning with a description of the Fraunhofer lines in the solar spectrum, he showed by means of numerous lantern slides that cool vapour exists in the upper atmosphere of the sun. The orb that we see is that of the photosphere, while above it is the chromosphere, which may be called the sun's atmosphere. In this, red masses of vapour protrude beyond the orb, known as prominences, their composition consisting chiefly of hydrogen and calcium vapour. Beyond these layers is the corona.

Dr. Satterly then discussed the flash spectrum, and explained how it is obtained. As it occurs when only a narrow streak of the disc can be seen, it is possible to dispense with the slit of the spectroscope. In this way we get a spectrum with curved lines, viz., a spectrum of the sun's limb. At a certain instant bright lines flash out in this spectrum, which is normally one of Fraunhofer lines. The different lengths of the curved bright lines show what part of the sun's atmosphere they come from. There is a depth of at least 20,000 miles of solar atmosphere. The connection between the corona and the sunspots was next dwelt upon. From one eclipse to another there are changes going on in the corona, and the photographs at different eclipses show different forms of the corona. But there is very little alteration in the corona during the five minutes or so of an eclipse. There are, however, changes in the velocities in the prominences from minute to minute.

When disturbances are taking place in the sun there are usually disturbances in the magnetic field of the earth. Various theories have been put forward to account for the corona, such as the pressure of light, etc., but none of them are satisfactory.

After questions by Mr. Miller, Dr. Chant, Mr. Inrig, and others, and an expression of the thanks of the audience to Dr. Satterly for his instructive paper, the meeting was adjourned.

November 13.—A regular meeting of the Society was held in the Physics Building at 8 p.m., the President, Mr. W. E. W. Jackson, in the chair.

The following were elected members of the Society:

J. A. Law, 14 Bingham Street, Kitchener.

John K. Cowan, P.O. Box 198, Oshawa.

H. F. Balmer, B.A., 917 Dovercourt Road, Toronto.

Mr. Jackson reported that during the week ending November 3 there was considerable sunspot activity, as many as 46 spots being counted in one group. A penumbral spot is now visible on the sun's disc.

Prof. C. A. Chant, referring to the announcement that Prof. G. H. Peters of the U.S. Naval Observatory had calculated tentatively that the time of sunspot minima was reached in the latter part of last February, expressed his belief that the minimum had been reached some time earlier. Mr. Jackson concurred in this view.

Mr. A. F. Miller made some remarks on the constellations which had received attention at the recent meetings of the Society, viz., Cygnus, Cetus, and Pegasus, to all of which he had been turning his attention and making some telescopic

observations, especially upon 61 Cygni, the star for which Bessel first announced a parallax, and also upon β Pegasi.

Quoting from a recent issue of the Harvard College Bulletin, Prof. Chant drew attention to the fact that O Ceti (Mira), which has a period of variability of about 332 days, but is somewhat irregular in its variations, had recently been proved to be a visual double star.

References were made to the recent deaths of three well-known members of the Society, viz., C. A. Bigger, who was president of the Ottawa Centre a few years ago; John Ellis, J.P., of Swansea, who used a large telescope in his recreations in astronomy; Wilson Taylor, B.A., formerly of St. Catharines. Referring to the late Mr. Taylor, Prof. Chant described the researches of the deceased at the University of Toronto upon surface tension, and the handsome benefaction of Colonel R. W. Leonard of St. Catharines for two years, to enable Mr. Taylor to prosecute his studies in that subject. A resolution was passed requesting the secretary to write a letter to each of the three bereaved families or friends expressing the sympathy of the Society's membership in their loss.

In accordance with the plan of describing a constellation visible in the night sky at each meeting, Mr. A. F. Hunter gave a 15-minute address on the Pleiades, illustrating the group by means of seven lantern slides. In particular, he dwelt upon their chief astronomical features, as their helium type, their extremely great distance (without measurable parallax), their recession from our own stellar system and their nebulosity; also, upon their foremost place in literature from the earliest ages, and especially their place as the beginning of the Pleiades year, when they reach the meridian at midnight, which R. G. Haliburton pointed out from his extensive researches into historical literature.

John A. Paterson, M.A., read an interesting paper on "Edward Emerson Barnard; the man, the philosopher, the astronomer." Barnard, so diligent in the domain of astronomy, was born in Nashville, Tennessee, December 10, 1857. His father had died before he was born, and his mother had to struggle to maintain him and his two young brothers. She impressed upon him self-reliance. He attended school only two months, which was all the schooling he received throughout his whole life. At nine years of age his mother found work for him with a photographer, and he took the place of a driving clock of a great camera placed on a roof, used to make enlargements of photographs. When still young, he fell in with an astronomical book by Thomas Dick, and thus found the chosen work of his life. In 1876 he purchased a telescope for $400, and in the following year (1877), when the American Association for the Advancement of Science met in Nashville, with Simon Newcomb as president, he received a new impetus and introduction into the field of astronomy. Amongst his achievements in astronomy, deserving of note, were: The discovery of 19 comets between 1881 and 1892, Jupiter's fifth satellite in 1892, and in 1916 the star with the greatest known proper motion. His published contributions to science number about a thousand. His death occurred on February 6, 1923.

Remarks in appreciation of the paper, and in regard to Barnard, were made by Mr. Jackson, Mr. Hunter and Prof. Chant.

In conclusion, Mr. Jackson referred to a former announcement by Dr. C. G. Abbot, making an estimate of some apparent decrease of the sun's heat in recent years. Dr. Abbot has lately stated that the solar radiation is back again to normal.

At Winnipeg

April 11.—The meeting was held in the usual place, the President, Mr. H. B. Allan, occupying the chair.

The Secretary-Treasurer reported on the subscriptions to the fund for a telescope, and on the condition of the treasury. He also reported on quotations received from various firms, and it appeared that somewhat more money than that already subscribed will be needed to purchase a suitable telescope.

The President called on Professor L. A. H. Warren for the lecture, entitled "Recent Astronomical Discoveries and Photographs." The lecture was profusely illustrated, some of the slides shown being very recent ones. Particular attention was given to the magnitudes of various celestial objects and systems, one slide showing that the entire orbits of the earth and of Mars could be included in the space occupied by either of two stars recently measured. The motion of some stars and other celestial objects was illustrated; in particular, the motion of various parts of spiral nebulae.

After remarks of appreciation and informal discussion participated in by the President, Professor Wilson, Professor Warren and Mr. Bastin, the meeting adjourned.

At Victoria

May 1.—A regular meeting of the Society was held in the Auditorium of the Girls' Central School, the President, Mr. W. E. Harper, in the chair.

Messrs. E. E. Blackwood and Gordon Shaw were elected members.

The President called on the following gentlemen to address the meeting:

1st. Mr. F. Napier Denison on "The Milne-Shaw Seismograph." The lecturer exhibited lantern slides of the instrument and also details of its parts, in particular the magnetic damping device was explained. Various records were shown, one being the earthquake at Kamtschatka. The remarkable sensitiveness of this seismograph was illustrated by its showing the effect of a light pressure of the finger on its concrete foundation and its indication of the expansion of the rocky Gonzales Heights when exposed to the sun's rays.

2nd. Dr. R. K. Young presented the results of the measurement of the plates taken in Western Australia to test the Einstein hypothesis. The method adopted by the Canadian party was a differential one. Plates were taken of the stars in the neighbourhood at the time of the eclipse and similar plates were taken of the same region when the sun was absent from that part of the sky. These plates were compared in turn with a plate of the same region taken through glass. This procedure involves measures of small quantities which is always more accurate than measuring large ones. The precautions which must be taken

to avoid errors arising from change of scale value of the plate, change of orientation, inclination of the plate, refraction, aberration, proper motion and parallax were explained in an elementary way and the way in which the mathematical solution took care of these factors and gave the Einstein effect was shown.

On the two plates which were secured about 25 stars were visible though only 18 were considered sufficiently good enough to measure. Several solutions were made, the first including all the stars, the second and third omitting some that seemed to give discordant results. In every case the solution yielded positive results and of about the magnitude predicted by Einstein. The final conclusion was, therefore, that a displacement of the stars existed in harmony with the hypothesis.

3rd. Dr. J. S. Plaskett on "The O-Type Stars." The spectra of the stars of O-type, which term includes those giving both bright and dark lines, were described and illustrated, and the temperatures of these, the hottest of the stars, were estimated as ranging between about 17,000 and 25,000 degrees Centigrade. The spectral lines, due to the elements hydrogen, helium, nitrogen, silicon, carbon, oxygen, magnesium and calcium are usually broad and diffuse and the radial velocities correspondingly uncertain. Further, about two-thirds of them show variability in velocity rendering the velocity determinations difficult and uncertain. The average velocity is about 25 km. per sec., considerably higher that the B-types, and preliminary determination of the absolute magnitudes from velocities and proper motions gives a mean value -3.5, about 2,500 times brighter than the sun. The velocities obtained from the sharp H and K lines of calcium are usually different from those given by the other lines, rendering doubtful the connection of the calcium vapour with the stars.

After the papers had been read, very interesting discussions followed.

Votes of thanks having been tendered to the speakers, the meeting then adjourned.

June 22.—Through the kindness of Dr. J. S. Plaskett the annual open-air meeting of the Society was held at the Dominion Astrophysical Observatory on the above date.

Dr. Plaskett explained the details of the 72-inch reflector and the clockwork for keeping it steadily directed on a given object. Unfortunately the weather conditions did not permit any observations being made. Mr. Harper, however, showed a number of interesting slides and the various instruments were on exhibition, so that a very enjoyable evening was spent by the members.

At London

The London Centre of the R.A.S.C. began its meetings for the autumn season on Friday, October 12, with Dr. H. R. Kingston, the President, in the chair.

Dr. Kingston gave a very interesting and instructive address on "Motion in and Beyond our Solar System." He pointed out that motion is one of the commonest phenomena on the earth. The ancients were familiar with the apparent motion of the heavens but were not able to prove that what appears

as motion of the stars is really earth motion. Dr. Kingston pointed out that photography has supplied us with a means for proving many things which were incapable of proof by methods known to the ancients. A number of slides were shown to illustrate motion as shown by photographs. The New Moon, Jupiter and Venus show trails of light, as do also the planetoids. The motion of the moon is shown by the occultation of Venus. The moons of Jupiter change in relative position. The planet Mars rotates on its axis. The stars have motion but their great distance from us prevents us from detecting this motion by ordinary means. However, by taking photographs many years apart, changes in the relative position of the nearer stars can be seen. Photography also shows that double stars have motion.

E. T. WHITE,
Secretary-Treasurer.

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